Issued November 24, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

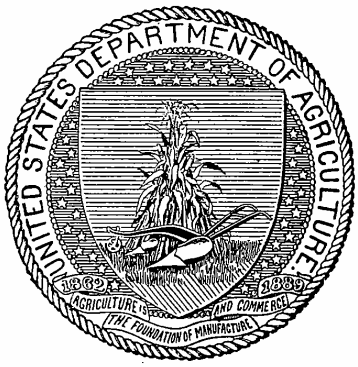
FOREST SERVICE—BULLETIN 101.

HENRY S. GRAVES, Forester.

WESTERN YELLOW PINE IN ARIZONA AND NEW MEXICO.

BY

THEODORE S. WOOLSEY, JR.,
ASSISTANT DISTRICT FORESTER, DISTRICT 3.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE,
Washington, D. C., July 25, 1911.

SIR: I have the honor to transmit herewith a manuscript entitled "Western Yellow Pine in Arizona and New Mexico," by Theodore S. Woolsey, jr., assistant district forester, district 3, and to recommend its publication as Bulletin 101 of the Forest Service.

Respectfully,

HENRY S. GRAVES,
Forester.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

WESTERN YELLOW PINE IN ARIZONA AND NEW MEXICO.[1]

PURPOSE OF THE STUDY.

Western yellow pine is to the Southwest what white pine is to the Northeast, or longleaf pine to the Southeast. The commercial forests of Arizona and New Mexico are three-fourths western yellow pine, which furnishes by far the greater part of the lumber used locally as well as that shipped to outside markets.

To describe the characteristics of the species and to explain the methods of management applied to it on the National Forests of the Southwest, in the hope that they may be applied as well, wherever possible, by private owners, is the chief purpose of this bulletin. It should serve also to assist Forest officers in their regular work, and to indicate opportunities for the purchase of Government stumpage in the National Forests of Arizona and New Mexico.

THE TREE.

FORMS IN THE SOUTHWEST.

The western yellow pine (*Pinus ponderosa* Laws) of the Southwest, sometimes called bull pine, scrub pine, and infrequently white pine, is the same species of tree as the yellow pine of the Pacific slope. In Arizona and New Mexico it is, in general, a smaller, knottier tree, with a larger and wider crown than in California, Oregon, and Washington, the result of a different situation and climate.[2]

Lumbermen and others distinguish two forms of the tree within the region, which they term, respectively, blackjack and yellow pine. The difference, however, is one of age and not of kind. Blackjack is merely the form which yellow pine assumes before it reaches the age

[1] Many of the figures and other data contained in this bulletin are the results of investigations by Messrs. G. A. Pearson, A. B. Recknagel, J. H. Allison, A. E. Cahoon, R. McMillan, A. D. Read, C. D. Faunce, E. I. Terry, H. B. Burrell, P. P. Pitchlyn, and H. M. Curren, of the Forest Service, to whom the author desires to acknowledge his indebtedness.

[2] In Forrest Service Bulletin 17, "A Check List of Forest Trees of the United States," a separate species of yellow pine, *Pinus ponderosa scopulorum,* was noted for portions of the Rocky Mountain region. It is now the judgment of Mr. George B. Sudworth, author of the Check List, that whatever differences exist between this form and that designated as *Pinus ponderosa* are due solely to differences in site and climate and not to any inherent difference in the trees themselves.

of 125 or 150 years, during which period its bark is dark red-brown or blackish, with narrow furrows, in strong contrast to the lighter, widely furrowed bark of mature trees. This distinction between the two forms, which will be followed throughout this bulletin, has also no basis in size, although the average yellow pine, being older, is necessarily larger than the average blackjack. Many blackjacks grown in the open, however, have a larger diameter than the average forest-grown yellow pine.

SOIL AND CLIMATIC REQUIREMENTS.

Western yellow pine is not fastidious in its soil requirements. It does best, of course, on deep, rich soils, yet it thrives on moist to dry gravelly loam, on limestone formations, on malpais or lava, in volcanic cinders, and in gravel. It seems to adapt itself, in fact, to the most impoverished sites, and saplings may be seen growing on dry, rocky south slopes. Trees in such situations, however, are often stag-headed and invite attacks from mistletoe and insects.

The distribution of yellow pine in the Southwest therefore depends upon altitude, with its corresponding rainfall and temperature, rather than upon the composition of the soil. Table 1 gives for certain situations in Arizona and New Mexico of known elevation and exposure the mean annual rainfall and the character of the yellow-pine stand in the vicinity.

TABLE 1.—*Character of yellow pine under different conditions of altitude, rainfall, and exposure.*

Localities.	Elevation.	Mean annual rainfall.	Character of yellow pine.
	Feet.	*Inches.*	
SOUTHERLY EXPOSURES.			
Santa Fe, N. Mex.	7,013	14.72	No stand.
Flagstaff, Ariz.	6,907	23.87	Good stand.
Fort Bayard, N. Mex.	6,040	15.20	No stand.
Fort Apache, Ariz.	5,200	18.90	Do.
Natural Bridge, Ariz.	4,743	18.05	Do.
NORTHERLY EXPOSURES.			
Cloudcroft, N. Mex.	8,650	24.39	Scattering in mixture with Douglas fir.
Luna, N. Mex.	7,300	16.58	Good stand.
Fort Wingate, N. Mex.	6,997	14.53	No stand; slightly below yellow-pine type.
Taos, N. Mex.	6,983	12.81	Scattering stand in Taos Canyon near by.
Williams, Ariz.	6,750	20.64	Good stand at slightly lower elevation.
Magdalena, N. Mex.	6,557	14.49	No stand.
Showlow, Ariz.	6,300	19.75	Scattering, on edge of woodland type.
Prescott, Ariz.	5,320	17.40	Scattering stand near town.

Table 1 would seem to indicate that on southern exposures below 7,000 feet, even 18.9 inches of rainfall does not necessarily insure the growth of yellow pine, but that on northern exposures above 7,000

feet the species will thrive with as little as 16.6 inches. In general, however, the indications are that no stand of large extent is likely where the annual rainfall is less than 20 inches. In Taos Canyon, with only 12.81 inches of rainfall, there are scattered individuals, but the presence of even these few trees is probably due to the moisture and shade from the canyon walls.

It is the variability of annual precipitation in the Southwest, coupled with drying winds, which make conditions for tree growth particularly trying. Droughts are periodic and severe, and undoubtedly impair the vitality of mature yellow pine and curtail the local distribution of the species. At Prescott, near which are commercial stands of yellow pine, the average annual rainfall for 35 years was 17.4 inches. Yet during that period there were 7 years with less than 12 inches, and two periods of 4 years each with an average annual rainfall of but 11.5 and 13.3 inches, respectively.

Increase in altitude brings, as a rule, increase in rainfall and climatic conditions in general more favorable to tree growth. Western yellow pine, however, is seldom found in pure stands of any extent above 8,500 feet, since it can not compete with the shade-enduring species which grow at the higher altitudes. It is present, in mixture with Douglas fir, at 10,300 feet, on the Gila National Forest. At the other extreme, it is not found ordinarily in any quantity below 6,500 feet, though in the sheltered beds of canyons and on favorable north slopes it grows at altitudes as low as 6,000 feet, and at one place at least, along Oak Creek in the Coconino National Forest, is abundant at 5,300 feet. Its presence here, however, is due to the moisture and partial shade from the canyon walls.

The heaviest extensive stands of yellow pine in Arizona and New Mexico are on the comparatively moist, rolling plateaus at elevations of from 7,200 to 7,800 feet. Probably the heaviest stand, though of small extent, in the two States, is on a well-watered flat north of Bellemont, on the Tusayan National Forest, at an elevation of 7,400 feet. Here 2 acres of unusually tall, clean-boled timbers scaled 72,000 board feet.

From April to July the heavy and continuous southwest winds, which lessen the air moisture, increase evaporation, and bake the surface of the soil, are particularly trying to tree growth. Even at Flagstaff, where the climatic conditions are considered favorable, the average wind velocity for the past five years has been 7 miles per hour, and the average humidity for the same period, 62 per cent.

SIZE AND LONGEVITY.

Yellow pine in the Southwest does not attain large size. Seven average logs are often necessary to make a thousand board feet, and on one section in the Tusayan National Forest the average was 10

logs to the thousand. During an inspection trip of six weeks over the Datil National Forest the largest yellow pine observed was 100 feet high and 50 inches in diameter, estimated to saw 3,420 board feet. A single bole on the Coconino National Forest scaled 4,300 board feet, while abnormal forked trees have scaled as high as 5,000 board feet. There are few yellow pines on the Forests of the Southwest over 120 feet in height, the highest so far observed being 129 feet. Trees more than 46 inches in diameter are also rare, the largest diameters recorded being 58 and 60 inches, on the Coconino and Manzano National Forests, respectively. Average sections are esti-

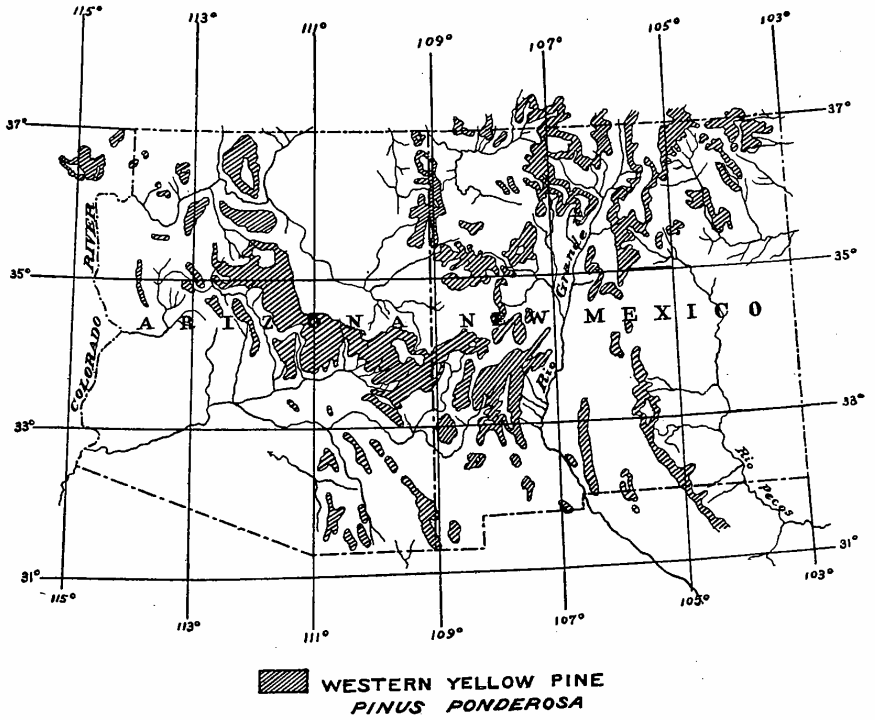


FIG. 1.—Distribution of western yellow pine within National Forests of Arizona and New Mexico.

mated at from 3 to 3.5 sixteen-foot logs to the tree, a number of others at from 4 to 4.5, while on the Sitgreaves Forest a few individual trees have been estimated at 7 logs. On a sale on the Coconino Forest, in a typical stand, 926 blackjacks averaged 19.2 inches in diameter, 36.9 feet used length, and 218 board feet merchantable volume. On the same area 1,863 yellow pines averaged 23.6 inches in diameter, 52.4 feet used length, and 522 board feet merchantable volume.

The blackjack form develops into the yellow-pine form when the tree is from 125 to 150 years old. Typical stands of overmature timber vary in age from 250 to 350 years, and the trees composing

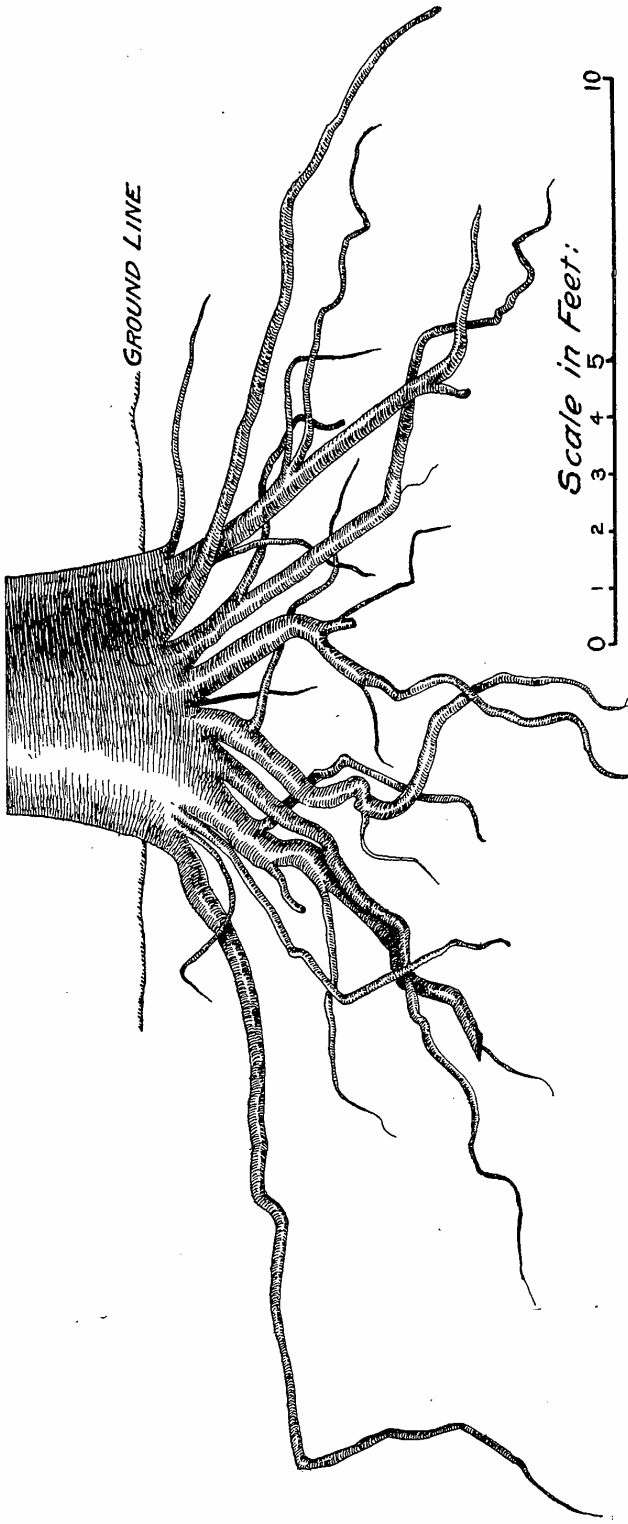


FIG. 2 (a).

them usually begin to decline in vigor when from 180 to 220 years old. From all stem analyses taken at random in timber sales on the Forests of the Southwest, the age of the oldest yellow pine was 418 years, while that of the oldest veteran yet recorded for the region was 489 years. It is likely that the periodic droughts of the Southwest tend to shorten the tree's life.

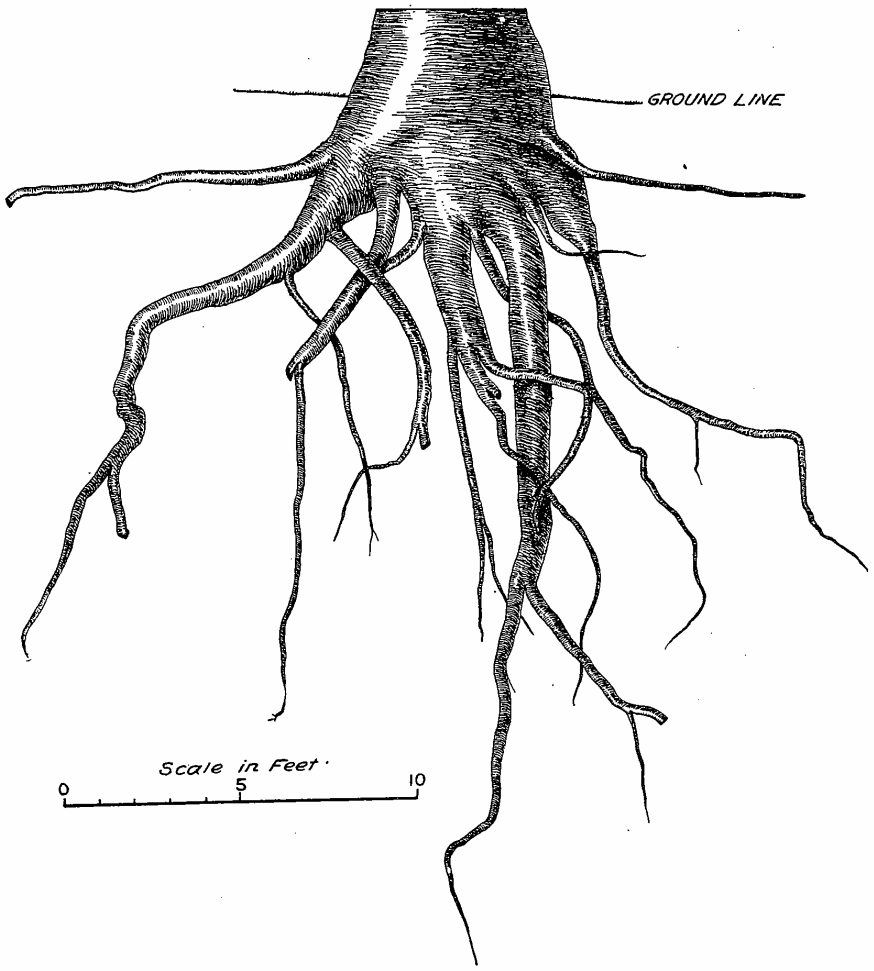


FIG. 2 (*b*).

ROOT SYSTEM.

Western yellow pine has a deep-reaching tap root and exceedingly long and strong laterals. Development of the root system in the seedling stage is very rapid. Seedlings sown on April 20, 1910, at the Gallinas nursery had an average height on October 3, after the growing season was over, of 1.12 inches and a tap root of 14.5 inches. Two-year transplants at the same nursery were 3.1 inches in height and had a tap root of 32.3 inches. Seedlings in the forest have

shorter tap roots, since the ground there is not so easy to penetrate. The usual length at the end of the first season is from 5 to 8 inches.

Figure 2 shows graphically the root system of a blackjack and a yellow pine. Both trees were growing on a moist to dry gravelly loam. The surface root system of each was uncovered and the area

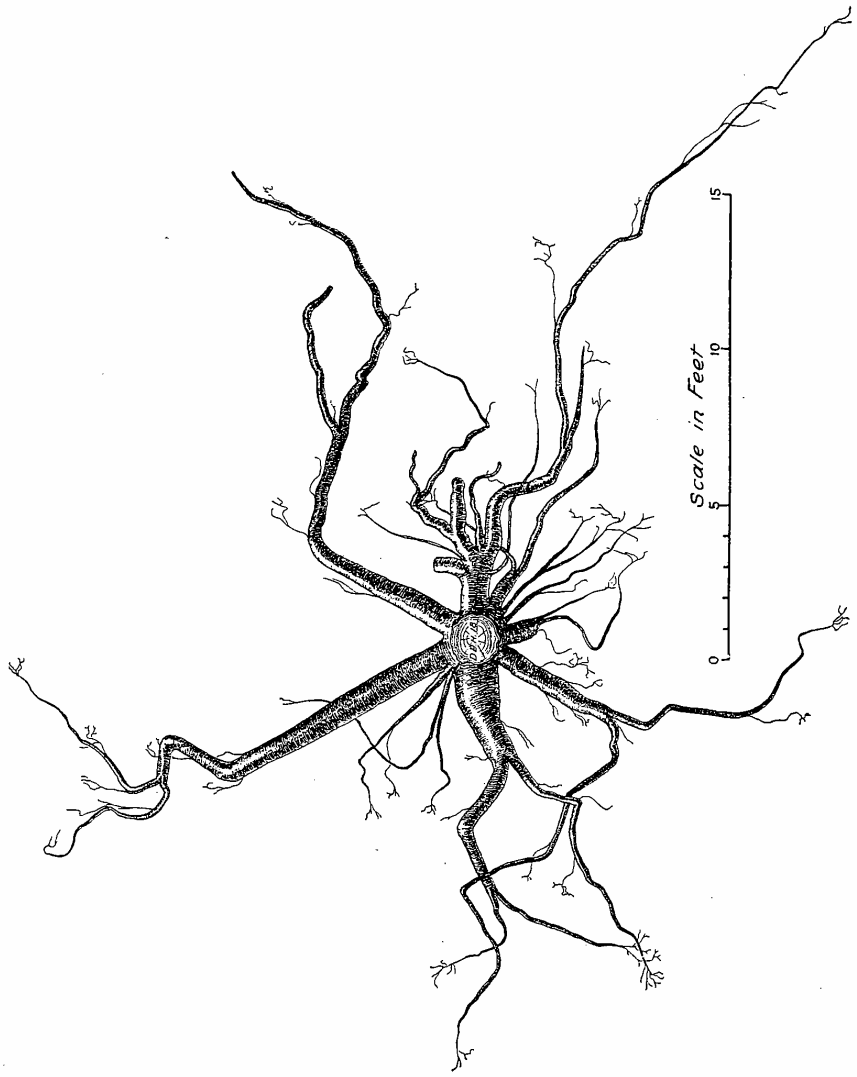


FIG. 2 (c).

divided into 4-foot squares, so that direction and length of each root could be carefully plotted. It will be seen that the roots of the blackjack extend over a large area, while those of the yellow pine, though larger in diameter, do not extend the same distance from the tree. Probably this is because, as the tree nears maturity, many of the roots become diseased and die off.

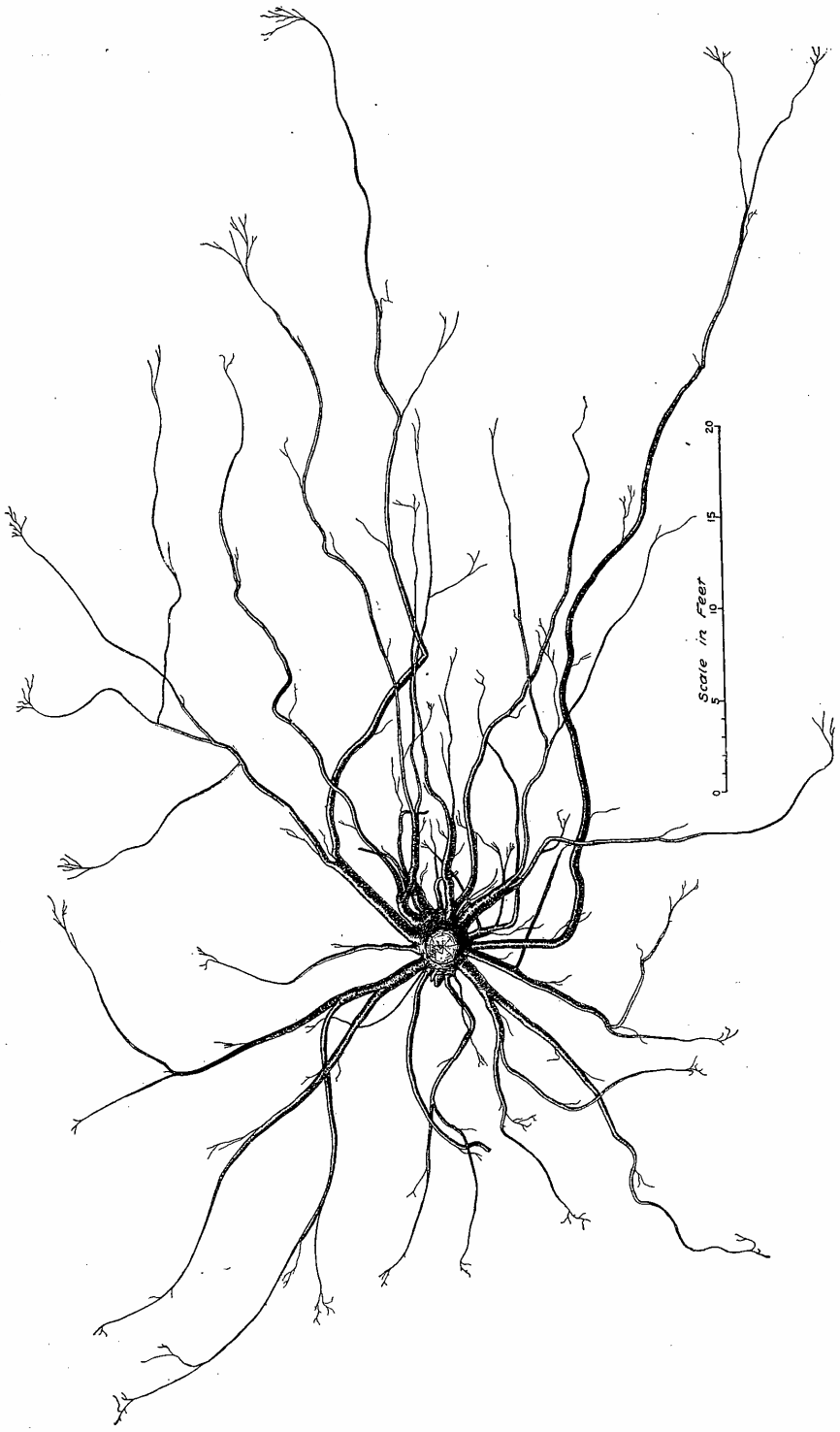


FIG. 2 (*d*).

Veterans have laterals extending from 60 to 100 feet from the base of the tree, and in extreme cases 150 feet. After maturity the tap root often decays.

MERCHANTABLE LENGTH.

The merchantable length of a tree—that is, the length of bole actually utilized in lumbering—depends upon the rapidity of its taper and the diameter limit to which it is cut in the top. The figures in Table 2, which express the merchantable length in relation to diameter breast high, are the result of actual logging operations, where the top diameter limit was 8 inches and the stand from two to three million feet to the section.

TABLE 2.—*Merchantable length of western yellow pine.*

Diameter breast high.	Merchantable length.	
	Yellow pine.	Black jack.
Inches.	*Feet.*	*Feet.*
14	32	22
17	41	32
20	47	41
23	53	47
26	59	53
29	64	57
32	69	.....
35	75	.....
38	80	.....
41	85	.....

CLEAR LENGTH.

Western yellow pine, when growing in pure stands, has but a short clear length in comparison with its total height. When in mixture with Douglas fir, however, natural pruning greatly increases the proportion of stem free of branches. Table 3 is based on the measurements of 800 trees on the Apache and of 65 trees on the Zuni National Forest.

TABLE 3.—*Clear length of western yellow pine compared with total height.*

Height.	Apache National Forest.		Zuni National Forest, pure western yellow pine, clear length.
	Pure western yellow pine, clear length.	In mixture with Douglas fir, clear length.	
Feet.	*Feet.*	*Feet.*	*Feet.*
50	7	.....	.....
60	12	25	8
70	16	25	10
80	19	31	12
90	22	37	14
100	.....	42	17
110	.....	47	22

BUTT AND TOP TAPER.

Table 4 gives separately for yellow pine and blackjack the taper in inches of the butt of a tree from 1 to 5 inches from the ground. In addition the table gives the reducing factor used to determine the breast-high diameter of a tree from the diameter of a stump 18 inches in height. The proper breast-high reducing factor for stumps of any height can be secured from the other figures of the table.

TABLE 4.—*Butt taper and reducing factor of yellow pine and blackjack, 1 to 5 feet from ground by 6-inch classes.*[1]

Breast-high diameter, class.	Distance from ground in feet.								Breast-high diameter reducing factor for stump 18 inches in height.	
	1 to 2		2 to 3		3 to 4		4 to 5			
	Inches outside bark.									
	Yellow pine.	Black-jack.	Yellow pine.	Black-jack.	Yellow pine.	Black-jack.	Yellow pine.	Black-jack.	Yellow pine.	Black jack.
Inches.										
8	0.6	0.8	0.5	0.5	0.3	0.3	0.2	0.2	1.0	1.0
14	1.0	1.2	.7	.8	.4	.4	.2	.3	1.3	1.5
20	1.7	1.7	1.7	.8	.8	.6	.6	.4	1.7	1.8
26	2.0	2.1	1.0	1.1	.7	.8	.5	.4	2.2	2.3
32	2.2	.....	1.2	.....	.9	.....	.7	.....	2.8	.....
38	2.3	.....	1.3	.....	1.0	.....	.8	.....	3.1	.....

[1] Based on 404 yellow pine and 200 blackjack on Zuni, Jemez, and Datil Forests.

In deciding between different top-diameter limits it is essential to know the average tapers of the top log. These are given in Table 5. According to the top taper as given for the Zuni Forest, the lumberman may choose between cutting a 16-foot yellow-pine log 6.9 inches at the small end, scaling 20 feet, or a 12-foot log 8.5 inches at the small end, also scaling 20 feet. Similarly, the table can be used to determine the differences in scale by cutting to different limits. Where the volume of scale is the same, the problem of what top limit should be used resolves itself into a question of manufacture.

TABLE 5.—*Top taper of yellow pine and blackjack 2 to 8 feet from merchantable limit.*

	Distance from merchantable limit, in feet.					Variety.
	0	2	4	6	8	
	Diameter inside bark, in inches.					
Jemez Forest	8.4	10.3	11.2	11.0	12.8	Yellow pine.
Zuni Forest	6.9	7.8	8.5	9.2	10.0	
Jemez Forest	7.5	8.7	9.4	10.0	10.8	Blackjack.
Zuni Forest	6.9	7.6	8.4	9.0	9.8	

TOLERANCE.

Western yellow pine is intolerant of shade, except in the seedling stage on very favorable situations. Investigations conducted at the Coconino Forest Experiment Station indicate that most seedlings get their start under protection of the seed trees, while in small openings the bordering stand shields the seedlings from the full effect of the weather. Saplings may exist under the shade of veterans, and a 74-year-old pole was found growing in full shade, though it had but a few more years to live. If once suppressed during the sapling stage, western yellow pine can not recover and develop into saw timber. Dense mature stands often decline in vigor and become stag-headed through lack of side light.

CAUSES OF INJURY.

INSECTS.

The *Dendroctonus* beetles, of which six species, including the Black Hills beetle, have been observed in Arizona and New Mexico, are perhaps the most destructive enemies of western yellow pine.[1] Records of depredations by the Black Hills beetle indicate that these have been far more continuous and extensive in comparatively humid sections, like the Black Hills of South Dakota and certain sections of Colorado, than under the more arid conditions of Arizona and New Mexico. The fact, however, that practically all of the *Dendroctonus* beetles are known to be primary enemies of western yellow pine in that they attack and kill perfectly healthy trees makes it important that Forest officers should watch for any evidence of the abnormal dying of pine timber, and should take prompt steps, if it is found to be due to the work of these beetles, to check further depredations, in accordance with the methods advised by the Bureau of Entomology.

FUNGI.

The bluing and red rot of western yellow pine are due to the attacks of fungi, and have been described fully in Bureau of Plant Industry Bulletin 36, "The Bluing and Red Rot of Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve." The blue fungus attacks the contents of the wood cells and not the cells themselves; consequently the blued wood is not rotten. The spores of the fungus which causes red rot lodge in bark grooves of dying trees, and after germinating grow through the cambium and sapwood, and attack and destroy the cell walls of the heartwood.

[1] For complete information concerning the work of these insects and their control, see Bureau of Entomology Bulletins 83, Part I, and 58, Part V, and Circulars 125, 126, 127, and 129.

In Arizona and New Mexico considerable losses occur through the bluing of the sapwood of saw logs left in the woods during wet weather. There are two ways to prevent this—one, to take the logs to the mill immediately, which is the best way; the other, to separate the logs so that the ends will be exposed to the air. Yet if logs are left for a few months in the woods during wet weather there is always likelihood of serious bluing, and in dry weather of season checks. Lumbermen speak of losing from one-fourth to one-third of their total cut of western yellow pine through defect, but this is certainly an exaggeration. Three large operators place the average loss through red rot at 20 per cent on the Coconino Forest, 25 per cent on the Zuni Forest, and from 5 to 10 per cent on a land grant in northern New Mexico. On an area of 80 acres in the Tusayan National Forest, bearing some very overmature timber, the total loss through defect and breakage, including unsound logs left in the woods, was 12.8 per cent. On a section in the Coconino National Forest the stand amounted to 4,009,180 feet board measure. The cull logs left in the Forest totaled 278,000 feet, and the cull deducted on logs hauled to the mill was 271,488 feet. The total loss through defect on the section, therefore, was 549,488 feet, or 13 per cent. Probably from 2 to 15 per cent is a fair amount to allow for loss, with a mean of from 5 to 8 per cent. In general, the timber on south slopes appears to be more defective than that on north slopes.

Pin rot in the form of spots one-eighth to one-fourth inch or more in diameter usually indicates serious interior rot. Ground or stem rot seldom extends more than from 4 to 6 feet above the ground. Usually it can be eliminated by butting a log 4 feet in length.

In October, 1910, Dr. Hedgcock tentatively identified the following fungi in a timber sale on the Tusayan National Forest: *Fomes pinicola*, *Trametes pini*, *Lentinus lepedius*, a genus of *Hydnum*, *Polystictus abietinus*, and *Fomes officinales*.

Fortunately, the dry climate of the Southwest retards decay, but defective trees which are left in the woods because they are too costly to log are a menace to the sound trees, and may cause considerable financial loss in the future through the spread of the fungus.

DROUGHT.

While the extensive root system of western yellow pine enables it to withstand the seasonable dry weather, many trees succumb to the periodic droughts which occur about once in every decade. In a sale of approximately 30,000,000 feet of timber on the Coconino National Forest, fully 10 per cent of the standing trees were dead, the result largely of unfavorable moisture conditions. Lack of moisture undoubtedly weakens the vitality of western yellow pine so that it can not withstand the ordinary insect and fungus attacks. Seedlings

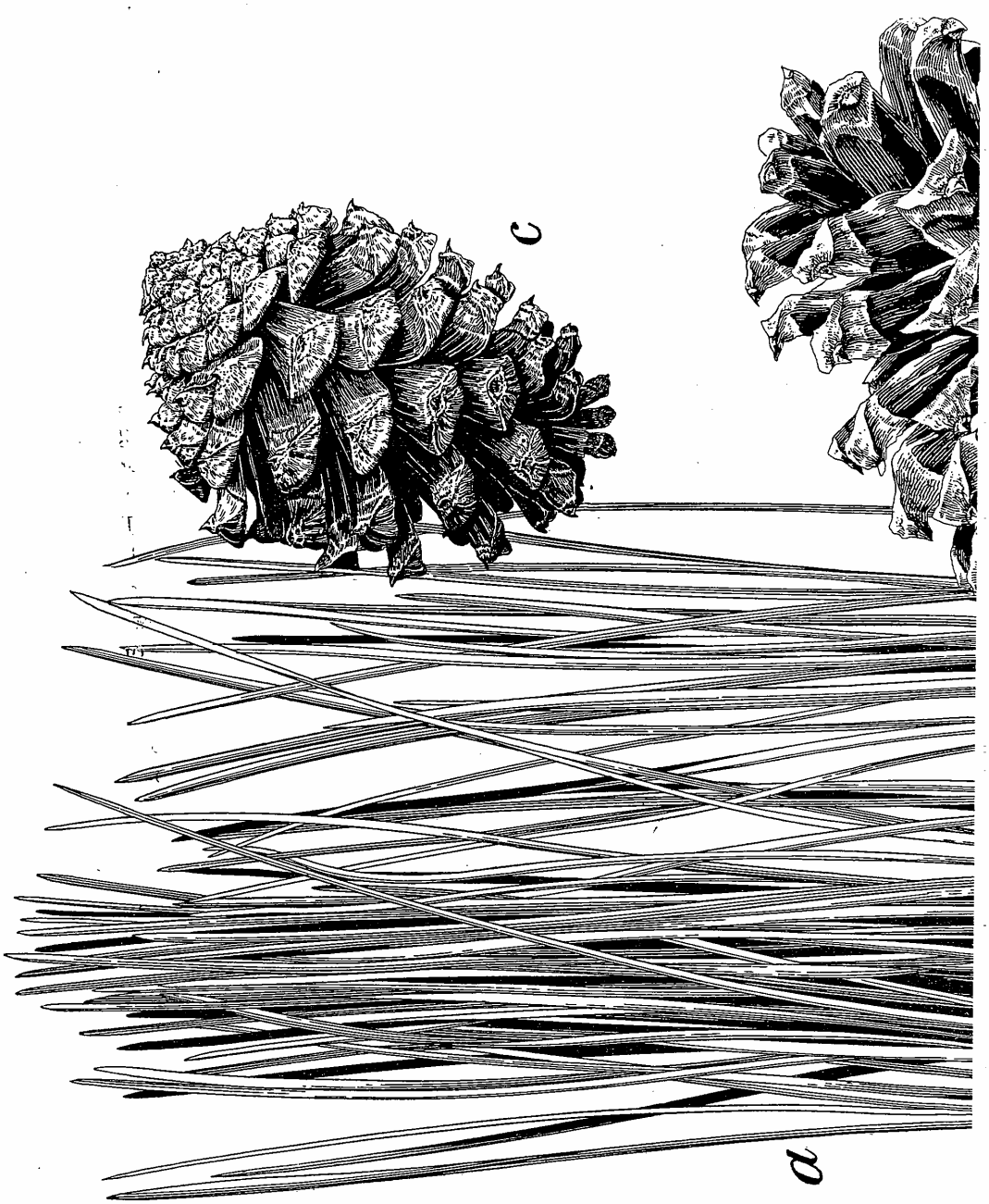

c
a

FIG. 3.—Western yellow pine, natural size, Arizona: *a*, leaf; *b*, seed; *c*, cones.

5998°—Bull. 101—11. (To face page 16.)

are particularly susceptible to drought, and ordinarily can not secure a foothold except under partial protection of older stands.

MISTLETOE.

Mistletoe, *Razoumofskya robuata*, is a serious menace to western yellow pine. In the Coconino and Tusayan National Forests there are large areas where over 60 per cent of the timber has been attacked. On some situations, particularly on the Sitgreaves Mountain, groups of blackjack with every tree infested are common. According to Dr. George G. Hedgcock, from 1 to 2 per cent of all the western yellow pine is attacked. The mistletoe usually starts in the forks of lateral branches and spreads as the tree grows, or it may even infect seedlings. The seeds of the mistletoe, which are sticky, are formed in the summer and ripen in the fall. When the seed covering bursts they may be shot from 5 to 20 feet, and often adhere to the bark of trees, soon developing roots which penetrate the cambium. Saplings attacked by mistletoe are deformed. Some of their branches are killed outright, their height and diameter growth is stunted, and the seed crop is lessened. In case of severe attack no seed is produced. A dry climate such as that of the Southwest lessens the danger from attack. Sometimes when a host tree is weakened the mistletoe may die from lack of nourishment.

STOCK.

Damage to seedlings and saplings from uncontrolled sheep and cattle may be excessive. When the range is overstocked cattle trample and injure seedlings, particularly in the vicinity of watering places, while saplings are occasionally horned and the bark partially rubbed off. If grass is scarce sheep nibble small seedlings, and when close-herded, as in crossing regular driveways, trample reproduction. Over extensive areas on the Coconino and Tusayan National Forests bands of sheep have stunted yellow pine seedlings by nibbling the terminal shoots. Some sheepmen claim that this was done chiefly by the "markers," or goats that go with every band. If sheep are salted continuously near reproduction the damage to the young seedlings is likely to be very great.

Goats are so destructive both to seedlings and to saplings that they should be excluded from western yellow pine stands. On the Datil National Forest is an area where yellow pine seedlings have been completely destroyed and saplings permanently injured by having their bark eaten from 4 to 5 feet above the ground. The value of properly regulated sheep and cattle grazing in securing reproduction, however, must be recognized, since it prevents the formation of a heavy mat of grass, and loosens the soil so that the seed can germinate. Grazing

before a reproduction cutting is beneficial, but after seedlings have come up and before they are firmly established it should be restricted.

LIGHTNING.

As a result of severe thunderstorms in the Southwest during the summer months, the damage to yellow pine from lightning is considerable. Often when a dry tree is struck a ground fire follows. On a sample plot of approximately 154 acres, on the Coconino National Forest, 1.5 per cent of the stand had been lightning struck. Trees are rarely killed outright, but lose a strip of bark from 6 to 10 inches in width, circling the tree spirally. Occasionally, however, trees are killed when struck. Even if lightning-struck timber remains standing, there is considerable loss in quality unless it is logged within one or two years. In the latter case the wood is merely blued, and can be cut into the lower grades. If, however, the trees are left standing for a number of years, lightning scars usually develop into serious rot.

FIRE.

Because of the open character of the stand and the fire-resisting bark, often 3 inches thick, the actual loss in yellow pine by fire is less than with other more gregarious species. A crown fire in mature timber is almost unheard of, and in a ground fire in the virgin forest young saplings often escape complete destruction, though with a fair wind and on a steep slope destruction of seedlings and saplings is often complete. It is after logging that the damage from fire is greatest, on account of the inflammable and unburned slash. The butts of mature trees are often fire scarred, but ordinarily this does not result in either death or decay. Even in the case of very serious scars, the butt log is usually sound, and much of the scar is eliminated in the slab. During recent years the yellow-pine type has been heavily grazed by sheep and cattle, and in consequence the grass is kept short, and the damage from fire very much reduced.

In June, 1910, a fire occurred on the Gila, Datil, and Apache National Forests which burned over about 60 square miles. The area burned was steep and rocky, with an unusual quantity of dry forage. An investigation showed that the injury to the yellow pine was confined very largely to the reproduction. On the area as a whole, from 40 to 50 per cent of the seedlings were killed. The greatest damage was done where the seedlings were in groups, and less where they were scattering. Of the saplings on the area, from 23 to 40 per cent were killed. While the greatest damage was done in groups, since there the fire seemed to burn with the greatest intensity, it was seldom that all of the trees in any one group were killed. A few trees with diameters from 6 to 10 inches, and even up to 20 inches,

had been killed, but none of a diameter above 20 inches. The injury to the mature yellow pine was very slight. Few of the larger trees were burned through the bark.

WIND.

The extensive root system of western yellow pine, especially the strong laterals, enables the tree, under ordinary conditions, to withstand severe wind pressure. In early spring, immediately after the snow has melted, and during the summer rains, however, the combination of soggy, water-soaked soil and high winds results in considerable windfall. Observations made on the Coconino National Forest show that, unless left in groups or otherwise protected, seed trees which remain after a stand has been removed are very likely to be wind thrown. Isolated trees that have always grown in the open can, of course, withstand the wind; the damage occurs when trees that have been growing with other trees in dense groups are suddenly exposed to its full force.

A tract of 480 acres on the Tusayan National Forest was logged during August, September, and October, 1909, after about one-third of the stand had been carefully marked for cutting. Yet in September, 1910, a year later, 8 blackjack and 10 yellow pine, totaling 2,250 and 8,520 feet board measure, respectively, had been blown down. The total windfall of 10,770 feet was, however, only 0.0067 per cent of the stand left after cutting. In this case the area was not exposed to the full force of the wind, and the marking was carefully executed with a view to preventing windfall. On less favorable situations and with less careful marking the loss has been as much as 2 per cent of the total stand left.

FROST AND SNOW.

Young seedlings of western yellow pine are susceptible to frost damage, particularly when they have not come up under the protective cover of brush. Moreover, dense reproduction, even from 2 to 5 feet in height, often suffers severely from either very early or very late frosts. In the Lincoln National Forest, along the Rio Bonito, there was considerable damage to young western yellow pine from frost in 1907. South of Sitgreaves Mountain, in the Coconino National Forest, dense reproduction was seriously damaged by frost in 1905. The results of experiments indicate that seedlings which have grown up under brush cover are not liable to frost, but may damp off during wet weather. Mature timber, also, is not damaged, and frost cracks in green timber are unknown. During the winter, however, frost in saw logs makes milling expensive unless the logs are thawed in a hot-water mill pond.

Since western yellow pine rarely occurs at the higher elevations, damage from snow is negligible. Occasionally a slender sapling is bent over after a particularly heavy storm, but the damage over large areas is infinitesimal. At higher altitudes, in mixture with Douglas fir, the young western yellow pine are afforded ample protection by the older stands.

MAMMALS AND BIRDS.

Undoubtedly an enormous quantity of yellow-pine seed is consumed each year by squirrels, mice, and chipmunks. When the seed supply is exhausted, squirrels eat the bark from the slender twigs of black jack, temporarily damaging the crown, but doing no permanent injury to the tree. Rodents nibble the roots of seedlings, and appreciable damage results, especially in plantations. Occasionally a tree is girdled by a porcupine.

Bird life is not plentiful in the Southwest, but what birds there are probably do more good by eating noxious insects than harm by damaging yellow-pine seed. Woodpeckers bore holes in dead trees and in live trees infested with insects, but healthy green timber is exempt from their attacks.

REPRODUCTION.[1]

Under poor moisture conditions, even with protection from fire and proper regulation of grazing, reproduction of western yellow pine is both difficult and uncertain. With sufficient rainfall, however, it is practically sure.

Since the seed of western yellow pine often does not germinate until the coming of the summer rains, its vitality is impaired by the usual period of drought during April, May, and June. Moreover, the seedlings that do come up are subjected to another drought from the latter part of September to November or December. Early frosts damage or destroy seedlings, particularly those not protected by a brush cover. Yet this same cover often induces damping off.

There are large areas on the Coconino and Tusayan National Forests, particularly of malpais formation, where reproduction is entirely lacking; yet this may in part be explained by recurring fires and overgrazing. Both of these are common in the Southwest, and account for lack of reproduction in many other places than the ones mentioned.

On the Prescott division of the Prescott National Forest, where the yellow-pine type is about half cut over, reproduction over the entire logged area is practically complete. Between Leoanard Canyon, on the Sitgreaves Forest and the southeastern boundary of the Coconino Forest reproduction is completely established in over 10,000 acres of virgin timber.

[1] See also Forest Service Circular 174, Reproduction of Western Yellow Pine in the Southwest, by G. A. Pearson.

Very complete data on reproduction in the Coconino and Tusayan National Forests, gathered in the course of reconnaissance estimates, and shown graphically in figure 4, give an excellent idea of the average quality and quantity of western yellow-pine reproduction on an area of 1,258,240 acres, where unfavorable conditions exist. Good reproduction means that seedlings already stock the ground; fair reproduction, that seedlings are scattered, but sufficient in places for a second crop; and poor reproduction, that new growth is entirely lacking or very incomplete.

GROWTH.

Under the climatic conditions of the Southwest western yellow pine is not a tree of rapid growth. It must, in fact, wage a continual warfare with nature for its very existence. The growing season is short, and frequently the seasonal drought lasts well into July, when the growing season is half over. In the seedling and sapling stage energy that must be expended in establishing the tree's root system results in dwarfing its development above ground.

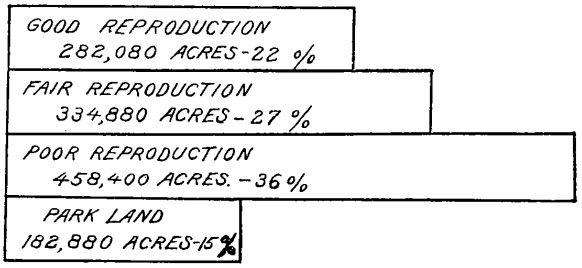


FIG. 4.—Relative quality of reproduction on Coconino and Tusayan Forests.

HEIGHT GROWTH.

The height growth of seedlings depends entirely upon local conditions, principally whether they are partially suppressed or grow in full light. The average figures in Table 6 are for seedlings growing in the open with some side shade.

TABLE 6.—*Height growth of seedlings.*

Age.	Colfax County, N. Mex.	Prescott Forest.	Apache Forest.	Datil Forest.	Jemez Forest.	Average.
Years.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
1	.....	.....	.....	.....	.....	.....
2	0.5	.....	0.4	.....	.....	.....
3	.7	.....	.5	1.0	.....	.....
4	.9	1.2	.6	1.1	.....	.....
5	1.1	1.6	.8	1.2	0.5	1.04
6	1.4	2.0	.9	1.3	.8	1.28
7	1.7	2.6	1.0	1.4	1.2	1.58
8	1.9	3.1	1.1	1.5	1.6	1.80
9	2.2	3.7	1.2	1.7	1.9	2.14
10	2.4	4.3	1.3	1.9	2.3	2.44
11	2.7	4.9	1.4	2.1	2.8	2.78
12	3.0	5.6	1.6	2.2	3.3	3.14
13	3.4	6.4	1.7	2.3	3.8	3.52
14	3.8	7.3	1.8	2.4	4.3	3.92
15	4.2	8.1	2.0	2.5	4.8	4.32

Under conditions best suited to its development—that is to say, in mixture with Douglas fir—the height growth of western yellow pine, as shown in Table 7, based on the measurements of 80 trees in the Apache National Forest, is most rapid at from 60 to 100 years of age. After 100 years the rate of height growth declines, until from 160 to 180 years it falls below the mean annual growth of 0.37.

TABLE 7.—*Height growth of western yellow pine in mixture with Douglas fir.*

Age.	Height.	Annual growth for last 20 years.	Age.	Height.	Annual growth for last 20 years.
Years.	*Feet.*	*Foot.*	*Years.*	*Feet.*	*Foot.*
20	5.0	0.25	200	95.8	0.28
40	13.5	.45	220	100.4	.23
60	25.8	.61	240	104.3	.19
80	40.3	.72	260	107.2	.14
100	54.0	.71	280	109.5	.11
120	65.4	.57	300	111.2	.08
140	75.0	.48			
160	83.2	.41	Mean annual growth..		.37
180	90.0	.34			

The relation between diameter and height is shown in Table 8, the figures in which are derived from hypsometer measurements. A comparison between height and age may be secured by substituting the ages in Table 7. On the Zuni Forest, distinction was made between blackjack and yellow pine, and the figures show that for the same diameters blackjack is shorter than yellow pine; yet on the Jemez Forest, where blackjack and yellow pine were also measured separately, this difference was not borne out, since the heights were practically identical.

TABLE 8.—*Height of western yellow pine on basis of diameter.*

Diameter breast high.	Apache Forest.		Datil Forest, pure western yellow pine.	Zuni Forest.		Prescott Forest, pure western yellow pine.	Jemez Forest.	Average.
	Pure western yellow pine.	With Douglas fir in mixture.		Black-jack.	Yellow pine.			
Inches.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
11	.....	.....	54	.....	.....	40	64	52.7
14	57	73	58	52	60	48	68	59.4
17	66	82	65	63	67	57	73	67.6
20	74	91	74	72	73	65	78	75.3
23	81	98	82	80	80	72	83	82.2
26	85	103	89	88	90	78	88	88.7
29	89	107	98	.....	98	83	95	95.0
32	91	110	.....	.....	105	87	104	99.4
35	92	112	.....	.....	110	90	.....	101.0

DIAMETER GROWTH.

Tables 9 and 10, based on the measurements of 400 trees on the Coconino and Tusayan National Forests, give the diameter of yellow pine and blackjack at different stages. It is apparent that the

mature yellow pine when in the blackjack form grew much slower than the present blackjack of the same size. This difference in diameter growth during the youth of the yellow pine is difficult to explain, unless it is because the more recent blackjack forests have been thinned by fire and the diameter growth stimulated. The current annual growth falls below the mean annual growth after 80 years in the blackjack form, and after 100 years in the yellow pine.

TABLE 9.—*Age of yellow pine and blackjack on basis of diameter breast high.*

Diameter breast high.	Yellow pine.	Blackjack.
Inches.	*Years.*	*Years.*
2	21.0	13.5
5	38.0	26.0
8	57.5	39.5
11	79.5	53.5
14	108.0	70.5
17	145.5	91.5
20	190.5	127.0
23	237.0	.....
26	285.0	.....

TABLE 10.—*Diameter growth of yellow pine and blackjack on basis of age.*

Age.	Blackjack.		Yellow pine.	
	Diameter breast high.	Growth per year.	Diameter breast high.	Growth per year of last 20.
Years.	*Inches.*	*Inch.*	*Inches.*	*Inch.*
20	3.60	.....	1.85	.....
40	8.15	0.227	5.25	0.170
60	12.20	.202	8.45	.160
80	15.50	.165	11.10	.132
100	17.95	.122	13.20	.105
120	19.70	.087	14.95	.087
140	20.80	.055	16.55	.080
160	.....	.....	17.95	.070
180	.....	.....	19.30	.067
200	.....	.....	20.65	.067
220	.....	.....	21.90	.062
240	.....	.....	23.20	.065
260	.....	.....	24.50	.065
Mean annual diameter growth	.....	.148	.....	.094

In Table 11, which is based on measurements of from 17 to 205 trees, on five National Forests, no distinctions were made between blackjack and yellow pine, although most of the trees measured belonged to the latter class. The average for the five Forests gives the diameter of 160-year yellow pine at 19 inches, while the figures for the Coconino Forest, in Table 10, gives it as 17.95 inches.

TABLE 11.—*Diameter of western yellow pine breast high on the basis of age.*

Age.[1]	Apache Forest.	Prescott Forest.	Jemez Forest.	Zuni Forest.	Datil Forest.	Average from curve.	Annual increment for last 20 years.
Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inch.*
20	2.6	2.8	4.0	2.2	2.0	2.6	0.130
40	5.2	6.1	8.2	4.6	4.2	5.8	.160
60	8.0	9.4	12.3	7.1	6.6	8.7	.145
80	10.7	12.0	15.8	9.4	8.8	11.4	.135
100	13.4	14.1	18.6	11.5	10.8	13.7	.115
120	16.0	16.2	20.8	13.2	12.5	15.7	.100
140	18.5	18.0	22.8	14.6	13.9	17.5	.090
160	20.9	19.4	24.6	15.9	15.0	19.0	.075
180	23.2	20.5	26.1	16.9	15.9	20.2	.060
200	25.3	21.6	27.6	17.8	16.7	21.3	.055
220	27.4	.....	.....	18.7	17.4	22.3	.050
240	29.2	.....	.....	19.5	18.0	23.1	.040
260	31.0	.....	.....	20.2	18.6	23.8	.035
280	32.5	.....	.....	20.9	19.1	24.5	.035
300	33.9	.....	.....	21.7	19.5	25.1	.030
Mean	.1130	.1080	.1380	.0723	.0650	.08366	.....

[1] 6⅔ years allowed for stump height.

VOLUME GROWTH.

Volume tables for western yellow pine are given in the Appendix. The increase in volume of single trees can be computed readily for a given number of years by applying the diameter growth, Tables 9, 10, or 11, to a tree of known diameter; and by finding the volume of the tree, Tables 29 to 32, on the basis of present and future diameters. The difference between the two trees represents the volume increment. It is often desirable to apply the increase in height and read the present and future volume from the diameter-height volume tables.

THE YELLOW-PINE TYPE.

The typical western yellow pine forest of the Southwest is a pure park-like stand made up of scattered groups of from 2 to 20 trees, usually connected by scattering individuals. Openings are frequent, and vary greatly in size. Within the type are open parks of large extent, whose origin may be due to peculiar soil conditions, such as hardpan, or in other cases to periodic flooding. What is known as Garland Prairie, in the Coconino National Forest, contains some 16,800 acres of rolling, open land. In a timber-sale area of 9,250 acres on the Tusayan National Forest, bordering the woodland type, and with a westerly and northerly exposure, 6,609 acres were forested, while the remainder, about one-third of the total area, was open land. At the lower limits of the yellow-pine type, piñon, alligator juniper, cedar, cypress, Gambel oak, and other woodland species occur in mixture with the pine. At the higher elevations are Douglas fir, white fir, limber pine, Mexican white pine, Engel-

mann spruce, aspen, and occasionally Gambel oak, until with increase of altitude yellow pine may be altogether replaced by pure stands of Engelmann spruce. In pure stands of yellow pine the ground cover is usually pine grass, bunch grass, and in openings grama of various species. The grasses are distributed in clumps or patches, interspersed with layers of pine leaves of various depths, according to the density of the sand. Underbrush is rare. Occasionally buck brush is found at the lower and briers at the higher elevations. Varying age classes give pure western yellow pine a variety of aspects. In places it is made up of thrifty pole stands of blackjack, with an occasional mature yellow pine fast declining in vigor. In others there may be an old mature stand of veterans, with complete reproduction beneath. On the limestone formations, with deep soil, the stand is usually more thrifty than on lava (malpais).

STAND.

AVERAGE STANDS.

To determine the number of trees per acre in an average stand of western yellow pine, surveys were made in different situations with varying conditions, and the results tabulated by 3-inch diameter classes.

Table 12 gives the results of valuation surveys on a portion of the Prescott National Forest, upon which a working-plan estimate was based, and which are indicative of average conditions in the more open yellow-pine stands on dry situations in the Southwest. The small number of trees per acre is typical. The largest tree recorded was 37 inches in diameter breast high.

TABLE 12.—*Average stand of western yellow pine on 128 strip acres, Prescott National Forest.*

Diameter breast high.	Trees per acre.	Diameter breast high.	Trees per acre.
Inches.		*Inches.*	
4- 6	7.7	25–27	0.5
7- 9	5.3	28–30	.2
10–12	4.2	31–33	.03
13–15	3.4	34–37	.03
16–18	2.7	Over 12	10.46
19–21	2.3	Over 18	4.36
22–24	1.3		

The number of trees per acre in average stands on the Coconino and Tusayan National Forests is given in Table 13. Here again, though under more favorable conditions than on the Prescott, the number of trees per acre is small. Since no healthy blackjack are marked for cutting in Government timber sales, except in thinnings, timber-sale estimates usually differentiate between blackjack and

yellow pine. The figures for the Coconino Forest are the average of 1,888 acres, chiefly on well-watered, rolling malpais flats, the stand frequently very dense; while those for the Tusayan Forest are the average of 5,920 acres on southeasterly exposures, with a dry soil and a considerable area of pure volcanic cinders, the stand rather an open one.

TABLE 13.—*Average stand of western yellow pine on timber-sale areas, excluding parks, Coconino and Tusayan National Forests.*

Diameter breast high.	Trees per acre.					
	Coconino.			Tusayan.		
	Black-jack.	Yellow pine.	Total.	Black-jack.	Yellow pine.	Total.
Inches.						
6–15	4.37	.....	4.37	4.31	.....	4.31
16–18	1.89	1.07	2.96	.52	0.55	1.07
19–21	.71	1.21	1.92	.40	.68	1.08
22–24	.53	2.36	2.89	.48	1.62	2.10
25–27	.17	1.55	1.72	.10	.66	.76
28–30	.07	1.03	1.10	.08	.53	.61
31–33	.01	.44	.45	.02	.31	.33
34–36	.....	.44	.44	.01	.31	.32
37–39	.....	.12	.12	.....	.04	.04
40–42	.....	.05	.05	.....	.04	.04
Over 12 [1]	4.88	8.27	13.15	3.11	4.74	7.85
Over 18	1.49	7.20	8.69	1.09	4.19	5.28

[1] Approximated.

TABLE 14.—*Maximum stands of western yellow pine based on 10-acre calipered sample plots.* (*Trees per acre.*)

Diameter breast high.	Carson Forest.[1]			Carson Forest.[2]			Alamo Forest.			Zuni Forest.			Jemez Forest.		
	Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.
Inches.															
4–6	.....	.....	.....	.....	.....	.....	0.3	.....	0.3	3.2	0.7	3.9	2.1	.....	2.1
7–9	2.4	.....	2.4	5.0	.....	5.0	2.2	.....	2.2				1.9	.....	1.9
10–12	2.0	1.4	3.4	4.3	0.4	4.7	4.6	.....	4.6	2.5	.5	3.0	1.5	.....	1.5
13–15	4.2	2.2	6.4	2.0	1.8	3.8	7.2	0.3	7.5	2.0	1.5	3.5	1.7	2.1	3.8
16–18	1.6	4.4	6.0	.7	3.7	4.4	8.4	1.1	9.5	.6	.9	1.5	2.5	3.4	5.9
19–21	.....	12.6	12.6	.4	6.7	7.1	6.2	3.8	10.0	.2	1.6	1.8	1.3	3.2	4.5
22–24	.....	11.2	11.2	.....	6.5	6.5	3.2	2.3	5.5	.....	1.5	1.5	.6	5.1	5.7
25–27	.....	7.0	7.0	.....	4.0	4.0	.6	2.2	2.8	.1	2.6	2.7	.2	4.3	4.5
28–30	.....	3.6	3.6	.....	1.9	1.9	.4	1.7	2.1	.1	2.6	2.7	.1	1.4	1.5
31–33	.....	1.8	1.8	.....	.6	.6	.....	1.0	1.0	.1	1.3	1.4	.....	2.2	2.2
34–36	.....	2.4	2.4	.....	.2	.2	.....	.6	.6	.....	.....	.....	.....	1.7	1.7
37–39	.....	.....	.....	.....	.....	.....	.....	.2	.2	.....	.4	.4	.....	.2	.2
40–42	.....	.2	.2	.....	.1	.1	.....	.....	.....	.....	.2	.2	.....	.1	.1
43–45	.....	.....	.....	.....	.....	.....	.....	.1	.1	.....	.....	.....	.....	.....	.....
46–48	.....	.....	.....	.....	.....	.....	.....	.1	.1	.....	.....	.....	.....	.....	.....
Over 12	5.8	45.4	51.2	3.1	25.5	28.6	26.0	13.4	39.4	3.1	12.6	15.7	6.4	23.7	30.1
Over 18	.0	38.8	38.8	.4	20.0	20.4	10.4	12.0	22.4	.5	10.2	10.7	2.2	18.2	20.4

[1] Five 1-acre plots. [2] Two 10-acre plots.

TABLE 14.—*Maximum stands of western yellow pine based on 10-acre calipered sample plots. (Trees per acre.)*—Continued.

Diameter breast high.	Coconino Forest.			Datil Forest.[1]			Apache Forest, total.[2]	Sitgreaves Forest.			Average of all plots.		
	Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.		Blackjack.	Yellow pine.	Total.	Blackjack.	Yellow pine.	Total.[3]
Inches.													
4–6	.....	.....	.....	0.57	.....	0.57	.....	2.2	.....	2.2	1.29	0.0	1.29
7–9	.....	.....	.....	1.6	0.1	1.70	.....	3.7	0.2	3.9	1.75	.04	1.90
10–12	1.3	1.1	2.4	2.07	.6	2.67	.....	3.0	.7	3.7	2.66	.58	2.88
13–15	1.8	2.6	4.4	2.43	1.33	3.76	5.4	4.1	.8	4.9	3.18	1.58	4.83
16–18	2.3	5.4	7.7	1.6	2.23	3.83	4.9	1.3	1.8	3.1	2.37	2.86	5.20
19–21	.9	6.3	7.2	1.17	2.4	3.57	5.0	.7	1.2	1.9	1.36	4.72	5.96
22–24	1.0	4.8	5.8	.43	2.43	2.86	4.6	.9	2.8	3.7	.76	4.58	5.26
25–27	.1	4.0	4.1	.03	1.8	1.83	4.8	.1	2.4	2.5	.14	3.53	3.80
28–30	.....	1.9	1.9	.03	1.3	1.33	2.2	.2	1.9	2.1	.10	2.03	2.15
31–33	.....	.7	.7	.03	.93	.96	1.1	.....	1.5	1.5	.02	1.25	1.15
34–36	.....	.....	.....	.03	.27	.30	.9	.....	1.1	1.1	.01	.78	.80
37–39	.....	.1	.1	.....	.13	.13	.2	.....	.3	.3	.....	.16	.17
40–42	.....	.2	.2	.....	.07	.07	.....	.....	.1	.1	.....	.12	.11
43–45	.....	.....	.....	.....	.07	.07	.....	.....	.....	.....	.....	.02	.02
46–48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.01	.01
Over 12.	6.1	26.0	32.1	5.75	12.96	18.71	29.1	7.3	13.9	21.2	7.94	21.64	29.46
Over 18.	2.0	18.0	20.0	1.72	9.40	11.12	18.8	1.9	11.3	13.2	2.39	17.20	19.43

[1] Three 10-acre plots.
[2] Blackjack and yellow pine calipered together.
[3] Includes Apache under "Total."

MAXIMUM STANDS.

Figures for a number of the heaviest stands on the Forests in Arizona and New Mexico, on each of which the local officers selected the heaviest 10 acres that could be found, are given in Table 14. Trees above 12 inches breast high represent all that would ordinarily be merchantable under present market conditions if the stands were cut clean, while those above 18 inches represent the usual cut in a Government timber sale, subject, of course, to local variations. Even on these maximum stands the average number of trees per acre over 12 inches in diameter is only 29.46 and over 18 inches only 19.43. Out of all the areas there was only one tree over 45 inches in diameter and only three trees over 42 inches. No trees were found which contained over five logs, although on the Apache Forest there were 31 five-log trees on the 10 acres measured. Of blackjack over 26 inches in diameter, there was an average of only 0.27 per acre; over 12 inches, 7.94; and over 18 inches, 2.39.

What is probably the heaviest stand of pure western yellow pine in the Southwest is shown in Table 15. It consists of an irregular strip of 2 acres on the Tusayan National Forest. The trees are all long-boled yellow pine of good quality. The average of 35.4 trees per acre shows the unusual density of the stand, yet there are 11 trees with diameters over 30 inches breast high and 22 trees which will yield five logs.

TABLE 15.—*Maximum stand on 2-acre sample plot, Tusayan Forest. (Trees per acre.)*

Diameter breast high.	Estimated number of 16-foot logs to trees.				
	2	3	4	5	Total.
Inches.					
16–18	0.5	.....	0.5	.....	1.0
19–21	.5	0.5	1.0	.....	2.0
22–24	.5	1.5	2.0	1.5	5.0
25–27	.....	.....	3.5	5.5	9.0
28–30	.....	.5	1.0	10.5	12.0
31–33	.....	.....	1.0	2.5	3.5
34–36	.....	.....	.....	1.5	1.5
37–39	.....	.....	.....	.5	.5
Over 18	1.0	2.5	9.0	22.0	34.5

FULLY STOCKED STANDS.

The open and grouplike character of even the heaviest existing stands of western yellow pine in the southwest prevents the figures for maximum stands from being a fair measure of what an area is capable of producing if fully stocked; that is, when the trees are evenly distributed over it at distances apart conducive to their best growth. Here and there, however, are small areas that may be considered fully stocked, though these are seldom over 1 or 2 acres in extent. An example of a fully stocked stand was noted on the Zuni Forest, where on an area of 24 feet by 78 feet, comprising one twenty-third of an acre, were 8 splendid veterans, averaging over 100 feet in height, and from 23 to 35 inches in diameter breast high. If this same density were maintained it would give a stand of about 184 veterans per acre. Two sample plots on the Datil National Forest, figures for which are given in Table 16, illustrate the grouplike character of even a fully stocked stand when grown under natural conditions. Figure 5 shows graphically the location of the trees on one plot. Through almost all stages of growth the openings remain approximately the same size until gradually the parent stand dies out, the small blanks become stocked with seedlings, and the cycle is complete.

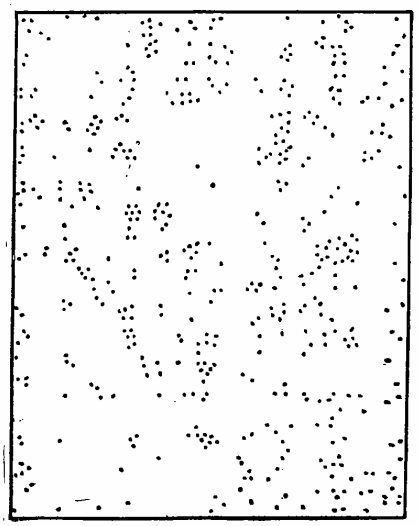


FIG. 5.—Distribution of blackjack on 5-acre plot.

The figures given in Table 16 for two fully naturally stocked stands of blackjack are an indication of the maximum stand capacity for soil

of moderate fertility. A plantation on similar soil even without thinnings would exceed these stands.

TABLE 16.—*Two fully stocked stands of blackjack.* (*Trees per acre.*)

Diameter breast high.	Blackjack 62 years old, 34.3 feet high.	Blackjack 82 years old, 42 feet high.	Diameter breast high.	Blackjack 62 years old, 34.3 feet high.	Blackjack 82 years old, 42 feet high.
Inches.			*Inches.*		
4-6	21.6	19.2	25-27	0.0	0.2
7-9	39.4	40.8	28-30	.0	.....
10-12	38.4	43.8	31-33	.2	.....
13-15	21.6	27.4	Over 12	38.0	46.2
16-18	13.0	11.6	Over 18	3.4	7.2
19-21	2.6	5.6			
22-24	.6	1.4	Total over 4..	137.4	150.0

YIELD.

AVERAGE AND MAXIMUM YIELD.

As compared with the Pacific coast, the yield of western yellow pine in Arizona and New Mexico is relatively small. On the Tusayan and Coconino National Forests are approximately 1,317,000 acres of the western yellow-pine type. Allowing for the underrun of past estimates, the stand of western yellow pine on the average acre for the entire area, including parks, barren land, and cut-over areas, is about 3,500 board feet to the acre, or 2,250,000 board feet to the section. The best township on the two Forests is estimated to cut 177,365,000 board feet, or, roughly, 7,700 board feet to the acre, which is approximately 5,000,000 feet to the section. The largest recorded cut in any lumbering operation within the Coconino and Tusayan National Forests was 9,522,000 board feet to the section. According to T. A. Riordan, president of the Arizona Lumber & Timber Co., however, this was an extraordinary section, and no other has cut within a couple of million feet of this quantity. On 5,920 acres taken as an average for a large timber sale on the Coconino Forest, the average stand per acre was blackjack 516 feet and yellow pine 3,299 feet, a total of 3,813 feet. On another sale 2,135 acres averaged 725 board feet of blackjack and 5,797 of yellow pine, or a total of 6,522 board feet per acre. Exclusive of small parks and openings the average stand per acre on the forested area amounted to 7,390 board feet. On a timber-sale area of 9,520 acres on the Tusayan Forest, of which 6,609 acres is forested and the remaining 2,911 made up of open parks, the total cut is estimated at 31,000,000 board feet, or 3,256 board feet per acre. For the forested area only the cut will average 4,691 board feet per acre. On this sale about 25 per cent of the stand was left uncut to reseed the ground.

Both Mr. A. B. McGaffey and Mr. Charles F. Wade, of Albuquerque, N. Mex., remember a section within the Zuni National Forest on private land that cut slightly over 7,000,000 board feet, though exact figures are not available. Mr. Wade reports that during the period from June, 1907, to May, 1910, the largest cut from any section of which he has knowledge was 5,458,256 board feet. What he considers an average cut during this period from 6,720 acres totaled 35,282,462 board feet, or 5,250 board feet per acre. This would amount to approximately 3,333,000 board feet per section. As a guide in cruising, a poor stand might be considered as running 1,000,000 feet to the section, a fair stand 2,000,000, a good stand 3,000,000, a heavy stand 4,000,000, and a very heavy stand 5,000,000. These figures, of course, are merely an approximation.

MAXIMUM YIELD ON SAMPLE PLOTS.

Maximum stands found on small areas prove that with artificial regeneration and a fully stocked stand, a large yield can be counted upon. Table 17 shows the yield upon twelve 10-acre sample plots on eight National Forests in the Southwest. As will be seen, the highest yield was found on the Jemez National Forest, where the sample plot averaged 1,303 board feet of blackjack and 15,800 feet of yellow pine per acre, or 17,103 feet in all. Next to this is the Coconino National Forest with 1,440 board feet of blackjack and 13,686 feet of yellow pine per acre, a total of 15,126 feet. The average of the twelve 10-acre plots gives 1,457 board feet of blackjack and 9,665 of yellow pine per acre, or a total average per acre of 11,395 feet.

TABLE 17.—*Maximum yield per acre of western yellow pine from calipered sample plots.*

Forest.	Blackjack.	Yellow pine.	Total.	Forest.	Blackjack.	Yellow pine.	Total.
	Feet b. m.	*Feet b. m.*	*Feet b. m.*		*Feet b. m.*	*Feet b. m.*	*Feet b. m.*
Sitgreaves	1,371	10,980	12,351	Zuni	591	9,582	10,173
Datil	1,061	7,642	8,703	Do	1,637	9,060	10,697
Do	575	10,751	11,326	Jemez	1,303	15,800	17,103
Do	2,160	8,380	10,540	Carson [2]	579	12,359	12,974
Apache	[1]	[1]	14,401				
Alamo	5,308	8,041	13,349	Average	1,457	9,665	[3] 11,395
Coconino	1,440	13,686	15,126				

[1] Not separated. [2] Two 10-acre plots. [3] Includes Apache total.

On very small areas the maximum stand sometimes far exceeds those just given in the table, a fact due to the natural grouping or crowding so characteristic of the species. Five 1-acre plots on the Carson National Forest averaged 622 board feet of blackjack and 26,730 feet of yellow pine, a total of 27,352 board feet per acre. Perhaps the heaviest yield of western yellow pine for an area of 2 acres within the Southwest was found in the Tusayan National Forst.

Here the trees, which were all veterans, totaled by volume table analysis 66,110 board feet, or 33,055 board feet per acre. The enormous volume of single groups of mature trees is illustrated by a plot of one twenty-third of an acre in extent on the Zuni National Forest which totaled 8,767 board feet or 201,641 board feet per acre.

INCREMENT OF STANDS.

Table 18 gives the results of measurements of two 5-acre plots in a pure, fully stocked stand of blackjack, and shows the mean annual increment per acre that may be expected in a fully stocked stand of this species.

TABLE 18.—*Yield per acre of fully stocked blackjack.*

	Present age.	Average height.	Average diameter.	Number of trees per acre over 6 inches in diameter.	Total volume per acre.	Mean annual increment per acre.
					Board feet.	*Board feet.*
Plot 1	62	34.3	11,9	115.8	6,326	102.0
Plot 2	82	42.0	12.3	130.8	7,590	92.5
Average	72	38.1	12.1	123.3	6,958	96.6

No reliable yield table for western yellow pine in the Southwest exists, though it is planned during 1911 and 1912 to measure a large number of sample plots in fully stocked, even-aged stands, on which such a table may be based. A tentative yield table for yellow pine has been compiled on the Kootenai National Forest, in Montana. In that region a 70-year-old stand on second quality soil is estimated to yield 7,400 board feet per acre. In Table 18 it is shown that a 72-year-old stand in the Datil National Forest on average soil averaged 6,958 board feet per acre. In Montana there were 240 trees per acre, 9 inches in diameter and 51 feet in height, while on the Datil there were 123.3 trees per acre, 12.1 inches in diameter and 38.1 feet in height. Though the stand in the Southwest is larger in diameter, it is shorter than that in Montana, and there are fewer trees per acre. Adapting the Montana figures to the southwest, it may be estimated that on average soil a fully stocked stand of western yellow pine will give the following yield per acre:

TABLE 19.—*Estimate of the yield of average fully stocked stand of western yellow pine from 40 to 140 years.*

Age.	Yield per acre.	Age.	Yield per acre.	Age.	Yield per acre.
Years.	*Board feet.*	*Years.*	*Board feet.*	*Years.*	*Board feet.*
40	4,000	80	7,800	120	10,900
50	4,900	90	8,700	130	11,400
60	5,850	100	9,500	140	12,000
70	6,900	110	10,250		

When yield tables are not available and it is desired to estimate the future growth on cut-over land, it is necessary to caliper a certain per cent of the stand left. Compute the average acre and the size of the average tree, and apply the average diameter growth for any 10-year period desired. As an example, Table 20 shows the average stand on eight selected acres on good soil in the Coconino and Tusayan National Forests.

TABLE 20.—*Average number of trees per acre of different classes in virgin forest before cutting.*

Diameter breast high.	Yellow pine.			Blackjack.		
	Sound.	Diseased to be cut.	Dead.	To be saved.	Thinned to be cut.	Dead.
Inches.						
4–6	0.01	0.03	0.03	0.55	0.16	0.03
7–9	.16	.54	.16	3.23	.26	.09
10–12	.36	.37	.20	3.16	.33	.06
13–15	1.02	.26	.11	2.41	.13	.02
16–18	1.92	.39	.21	1.74	.15	.01
19–21	2.44	.24	.33	1.27	.01	.03
22–24	[1] 2.29	.31	.32	.53	.02	.....
25–27	1.97	.21	.20	.16	.....	.01
28–30	1.35	.19	.21	.04	.03	.01
31–33	.52	.06	.13	.03	.....	.....
34–36	.45	.05	.13	.....	.....	.....
37–39	.38	.01	.....	.....	.....	.....
40–42	.13	.02	.....	.....	.....	.....
43–45	.....	.....	.02	.....	.....	.....
Above 12	12.47	1.74	1.64	6.13	.34	.08
Above 18	9.53	1.09	1.32	1.98	.06	.05

[1] To be left for second cut in 20 years.

Ordinarily in a Federal timber sale all the merchantable diseased yellow pine would be cut, as well as the healthy yellow pine above 21 inches in diameter, and the blackjack in need of thinning. The dead trees yielding saw logs would also be marketed. Of the trees over 12 inches in diameter left on the ground, the average diameter for both blackjack and yellow pine is 17.8 inches. The stand over 12 inches in diameter left on the ground amounts to 1,054.3 board feet of blackjack, and 1,194.3 board feet of yellow pine, or a total of 2,249 board feet per acre. From Table 10 it appears that in 20 years the 17.8-inch blackjack will grow to 19.55 inches, and the 17.8-inch yellow pine to 19.15 inches. In addition, there will be trees of 12 inches and less in diameter that have in the meantime grown into the merchantable class. In 20 years the 11-inch blackjack will have a diameter of 14.30 inches, and the 11-inch yellow pine one of 13.10 inches. This gives in 20 years a total stand of 3,093 board feet per acre, composed of 1,418 feet of yellow pine and 1,675 feet of blackjack, a natural increase of 37.5 per cent, or about 2 per cent annually for the 20-year period.

The growth of stands will, of course, vary with the percentage of blackjack in composition. The more blackjack, the more rapid will

be the increase. Careful measurements on a simple plot of 336 acres on a cut-over area on the Coconino National Forest showed that of trees 10 inches and over in diameter, there were at present on the area 2,644 blackjacks, averaging 15.9 inches in diameter, and 814 yellow pine, averaging 21.7 inches. From Table 10 it is seen that a blackjack with a diameter of 15.9 inches will in 20 years grow to a diameter of 18.35; while a yellow pine, with a diameter of 21.7 inches, will grow to a diameter of 23 inches in the same period. Using volume Tables 29 and 30, these mean trees have a volume of 510 board feet, and will have in 20 years a volume of 808 board feet, showing a growth in volume for the 20 years of 63 per cent, or 3.15 per cent per year. This calculation does not allow for loss through lightning and decay, but since the total volume of blackjack and yellow pine at present classed as unhealthy amounts to 6,660 and 24,490 board feet, respectively, it is apparent that the growth would equal at least 2 per cent per year. This figure, of course, is for very favorable situations, where the total volume of blackjack is practically equal to the total volume of yellow pine left after cutting.

THE WOOD.

STRUCTURE.[1]

A discussion of the characteristics of western yellow pine wood is presented here as an aid in the identification and for a better understanding of its variable qualities. The characters helpful in recognizing the wood are treated under two heads: (1) The gross characters, and (2) the microscopic characters. Under the first head are considered such general characters as can readily be seen with the unaided eye or with a pocket lens magnifying from 4 to 6 diameters, while under the second is presented a full discussion of the minute structural characters of the wood.

GROSS CHARACTERS.

While generally the wood of western yellow pine is hard, compared with that of white pines, a good many trees yield wood closely resembling white pine in color, weight, and softness. However, in all grades of western yellow pine the late wood, the hardest part of the annual rings, is more pronounced, and therefore darker and harder than that of white pine, which has a more uniform structure. The heartwood of western yellow pine, very variable, but usually hard, is moderately heavy (30 pounds per cubic foot kiln dried), strong, and light reddish-brown in color. The sapwood is nearly white, usually varying from 3 to 6 inches in thickness (from 100 to 200 annual rings of growth).

[1] Prepared by George B. Sudworth, dendrologist, and C. D. Mell, assistant dendrologist, Forest Service.

On a smooth transverse section of the wood the annual rings of growth are distinctly visible, though more so in wood having wide rings (fig. 6, *a*) than in wood with very narrow rings (fig. 6, *c*). The width of the annual rings varies greatly in different trees (fig. 1, *a*, *b*, and *c*), which in great measure accounts for the difference in the character and quality of the wood. Very old trees, as well as young ones growing on poor soil, invariably develop narrow annual rings. Such wood has a more uniform structure than that with wider rings, and superficially often resembles white pine. Thrifty, rapidly grown trees have wood with wide annual rings, in each of which there is a conspicuous contrast between the soft early wood and the hard late wood.

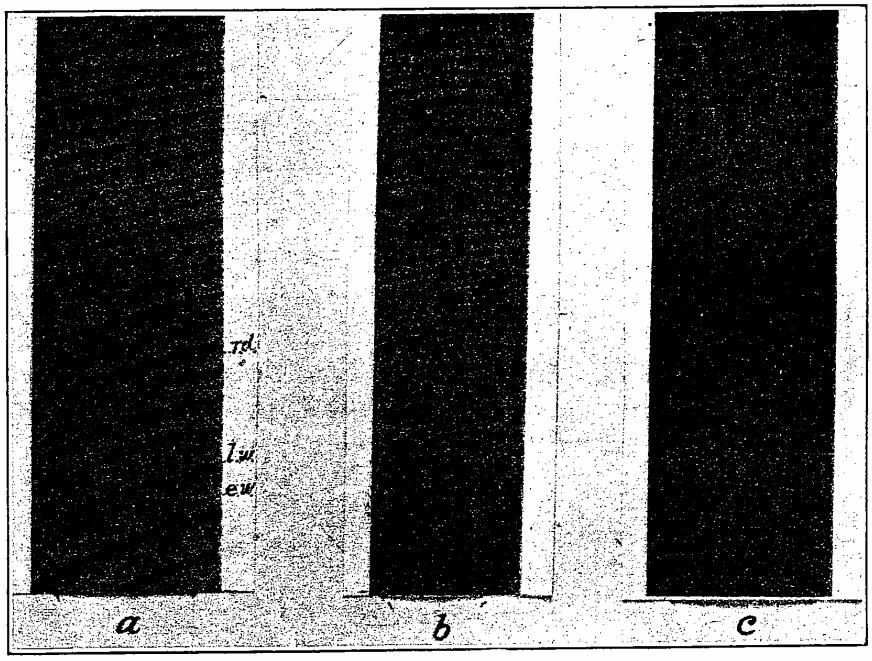


FIG. 6.—Various types of western yellow pine wood as shown in smooth transverse sections photographed natural size; *e. w.*, early wood; *l. w.*, late wood; *r. d.*, resin ducts.

The contrast between the wood formed in early spring (fig. 6 *a*, *e. w.*) and that formed later (fig. 7 *a*, *l. w.*) is due partly to the general reduction in the radial diameter (fig. 7, *f. t.*) of the cell elements, as growth advances from the early to the late wood, and partly to the greatly increased thickness of the cell walls (fig. 7, *l. w.*) of the late-wood portion of the ring. The cell cavities in the wood formed in the early spring are usually much larger, and the cell walls thinner than in the wood formed later. (Fig. 7 *b*, *e. w.*). These two parts of the annual ring show a gradual transition from one to the other (fig. 7 *a*, *a. r.*) which is characteristic and often serves to distinguish western yellow pine wood from that of other

pines which show a more abrupt transition from early to late wood. The width of the annual rings and the proportion of early wood to late wood in them are characters which determine the quality of western yellow pine wood as recognized by lumbermen. Where the growing season is short, and other conditions are unfavorable to rapid growth, the greater part of the annual ring consists of early wood, and very little contrast is seen between the rings, because of the small amount of late wood produced. A small proportion of this wood means a lack of the more stable wood elements, and hence a deficiency in strength. Lumber characterized by layers of growth of this type is comparatively brittle, and may be rather easy to work, features which permit narrow-ringed grades of western yellow pine

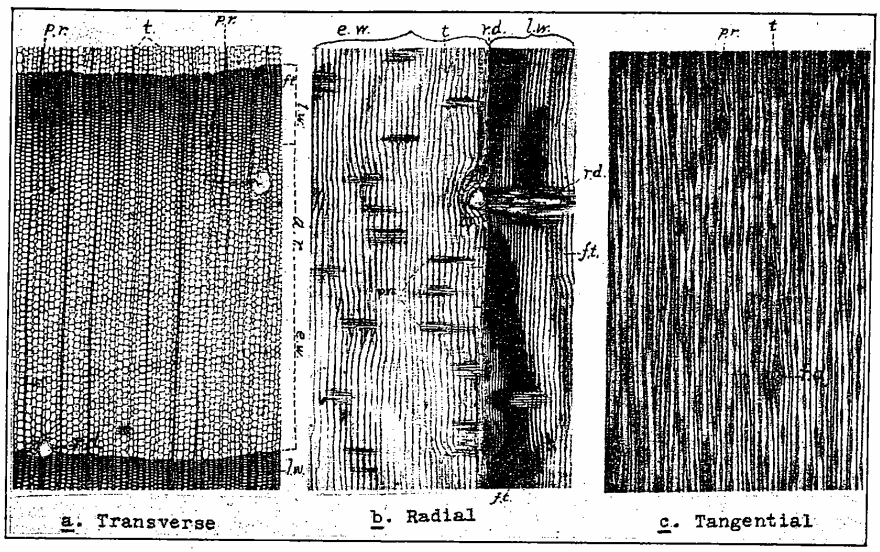


FIG. 7.—*a*, transverse, *b*, radial, and *c*, tangential sections of western yellow pine, magnified 20 diameters; *a. r.*, annual (layer) ring; *e. w.*, early wood; *l. w.*, late wood; *p. r.*, pith rays; *r. d.*, resin ducts; *t.*, tracheids; *f. t.*, flattened tracheid.

to be substituted for white pine. Where, however, the growing season is longer and conditions are favorable to rapid growth the ring produced each season is much wider, and shows a strong contrast between its early and late wood, the latter being particularly abundant. The cell elements in the late wood of trees grown under these conditions are stronger, more durable, and as a result of the large proportion of late wood the lumber of fully matured trees is of the best quality. Resin ducts, which are conspicuous in this wood and easily observed in a smooth transverse section (fig. 6 *a*, *r. d.*), are confined, in annual rings of average width, to the transitional part of the ring between the early and late wood, but in very narrow rings resin ducts are usually present only in the late wood. These characteristics are, to some extent, helpful in distinguishing western yellow

pine wood from that of such closely related species as shortleaf, longleaf, and other pitch pines.

In a smooth end view of the wood the pith rays are visible to the unaided eye only as faint, narrow, radially disposed lines, but they are plainly visible under a hand magnifier. (Fig. 7 *a*, *p. r.*) The microscopic characters of the pith rays furnish the most reliable means of distinguishing the wood of western yellow pine from that of closely related species.

MICROSCOPIC CHARACTERS.

In a transverse section[1] of the wood (fig. 7, *a*), the inner and outer boundaries of each annual ring are distinctly outlined (fig. 7 *a*, *a. r.*), while within the ring is seen a very gradual transition (fig. 7, *e. w.* and *l. w.*), the latter from early to late wood usually occupying from one-fourth to one-third of the width of the annual ring. This gradual transition is in striking contrast to the abrupt changes from early to late wood seen in shortleaf and longleaf pine. Tracheids (fig. 7 *a*, *t.*) in early wood are round or polygonal, quite uniform in size, and arranged in regular radial rows between the pith rays, while in late wood they are compressed radially so that the cell cavities appear elongated (fig. 7 *a*, *l. w.*), or are sometimes completely obscured (fig. 7 *a*, *f. t.*). The very prominent resin ducts occur chiefly in the early wood (figs. 7 and 8, *r. d.*). The main passage in these, a continuous channel, is lined moderately thin-walled much-flattened resin-secreting (epithelial) cells (fig. 8, *ep. c.*). The pith rays (figs. 7 and 8, *p. r.*) are of two kinds, one with resin ducts and one without ducts. Those without resin ducts are more abundant and always one cell wide, and are separated from one another by from 1 to 20 rows of tracheids.

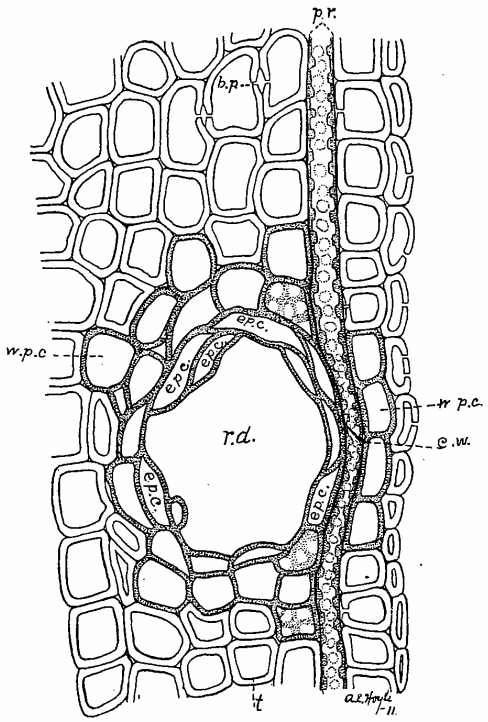


FIG. 8.—Transverse section of a resin duct with the surrounding tissue magnified 250 diameters; *r. d.*, resin duct; *ep. c.*, epithelial cells; *w. p. c.*, wood parenchyma cells; *t.*, tracheids; *b. p.*, bordered pits; *p. r.*, pith rays; *c. w.*, cross walls.

[1] The section must be cut precisely at right angles to the vertical axis of the tree.

The *radial section*[1] (fig. 7, b.), exhibits the broad tracheids (*t.*) of early wood (as seen in longitudinal section) and the radially flattened tracheids of late wood (fig. 7 *b*, *p. r.*). Ordinarily pith rays, those without resin ducts, are from 1 to 20 cells high, and always 1 cell wide, while rays with resin ducts, the more conspicuous form, are from 4 to 6 cells wide and from 10 to 25 cells high. Resin ducts within the pith rays communicate with the resin ducts (fig. 7 *b*, *r. d.*) running parallel to the axis or lengthwise of the trunk and its branches.

A *tangential section*[2] (fig. 7, *c*) of western yellow pine wood shows two kinds of pith rays (as seen in transverse section) which together constitute about one-tenth of the volume of the wood and are composed of continuous rows of short cells extending in a radial direction (from the center or pith of the tree toward the bark). One form of ray consists of a single row of cells, as noted above, while the other is made up of from 4 to 6 rows of cells, including also a resin canal.

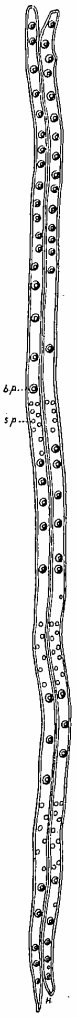


FIG. 9.—Two tracheids magnified 50 diameters; *b. p.*, bordered pits; *s. p.*, simple pits.

CHARACTERISTICS OF CELL ELEMENTS.

The following is a more detailed description of the cell elements pointed out as visible in transverse, tangential, and radial sections of the wood.

Tracheids (figs. 7 *a*, *t.* and fig. 9), which form the principal bulk of the wood, vary from 1.7 to 3.2 mm. in length, with an average length of about 2.5 mm. Those of the early wood have an average diameter of 0.05 mm., while tracheids of late wood have the same tangential diameter, but are considerably narrower radially. The length of tracheids varies not only in different parts of the same tree, but within the same annual ring at the same distance above ground. The average length of tracheids in both the trunk and branches increases from the center toward the outside of the trunk until the tree reaches its maximum height growth, after which the length remains nearly constant. The average length of tracheids increases also from the base of the tree upward until the tree attains its maximum height growth, after which it again decreases. The great-

[1] Unless cut accurately with its surface exactly parallel with a plane from the center to the circumference of the tree the section will present a misleading view.

[2] This should be cut in a plane exactly perpendicular to the pith rays.

est length of tracheids is usually less in the branches than in the trunk; the length in the branches, however, depends upon the part of the trunk from which they arise. Moreover, the length of tracheids in branches increases upward for some distance from the point where the latter are given off, and then gradually diminishes again. It is difficult therefore to determine the mean average length of tracheids in western yellow pine wood, particularly because the tree has such a wide natural range and grows under a great variety of soil and climatic conditions. As already pointed out, the length of cell elements of this wood is determined by the character of the soil, soil moisture, and the length of the growing season.

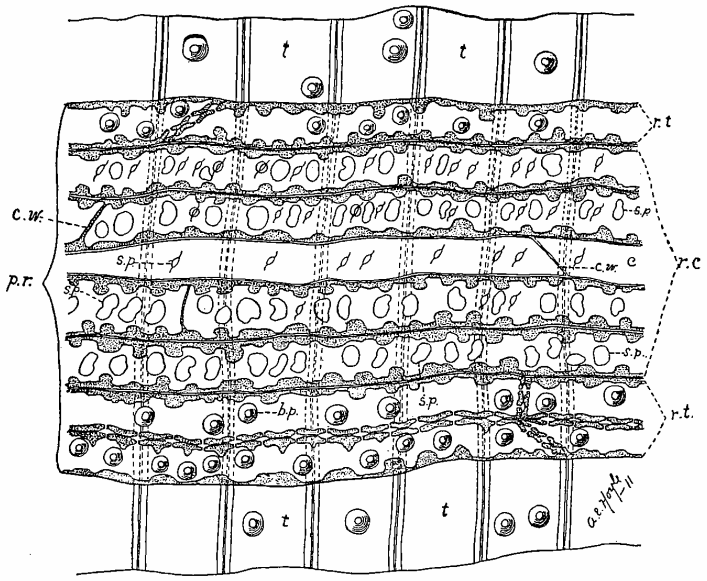


FIG. 10.—An ordinary pith ray cut longitudinally (radial section), magnified 250 diameters; *p. r.*, pith rays; *r. t.*, ray tracheids; *r. c.*, ray cells; *c.*, thin-walled ray cells; *b. p.*, bordered pits; *s. p.*, simple pits; *t.*, tracheids.

Tracheids (fig. 9) differ from the wood fibers of broadleaf trees in possessing bordered pits, while their ends are blunt and often slightly curved, due to the manner in which these elements overlap. The bordered pits of tracheids in early wood (fig. 9, *b. p.*) are arranged in one (rarely two) rows on the radial walls. In late wood the tracheids are compressed radially to such an extent that the pits are slit-like and usually smaller and less numerous. Where pith ray cells are in contact with tracheids, the communicating pits (fig. 9, *s. p.*) within the walls of the latter are small and simple, i. e., without border, and arranged chiefly in two vertical rows.

Pith rays (fig. 7 *a*, *p. r.*) appear in transverse section as radially disposed rows of elongated cells with vertical or oblique cross walls (fig. 8, *c. w.*). The majority of the pith rays are only a single cell

wide (fig. 7 *c*, *p. r.*, and fig. 11), while others which contain resin canals are from 4 to 6 cells wide (fig. 12). In radial sections these rays are cut longitudinally (fig. 7 *b*, *p. rs.*), and are made up of two kinds of cells. Figure 5 shows the character of an ordinary pith ray 8 cells high. The cells in the upper row and those in the lower two rows (fig. 10, *r. t.*) are ray tracheids. These have teeth-like projections on their upper and lower walls, and bordered pits both in their side and end walls, characters which distinguish ray tracheids from the next inner row of cells (parenchyma cells), the latter having thick walls and large simple pits (fig. 10, *s. p.*) on the inside walls. There are from 1 to 5 simple pits within the width of each vertical tracheid (fig. 10, *t.*). The end walls of these parenchyma cells are thin or sometimes locally thickened (fig. 10, *c. w.*). Other parenchyma cells, with thin, smooth, entire, upper and lower walls, and partly absorbed cross walls, occur within the pith rays (fig. 10, *c.*). These parenchyma cells have small elliptical or oval pits (fig. 10, *s. p.*), from 1 to 4 of which usually occur within the width of each tracheid.

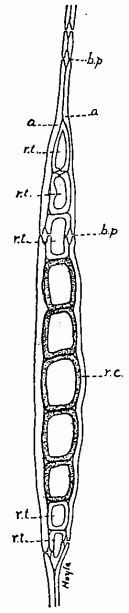


FIG. 11.—An ordinary pith ray as viewed in a tangential section magnified 300 diameters; *a*, walls of adjoining tracheids; *r.t.*, ray tracheids; *r.c.*, ray cells; *b. p.*, bordered pits.

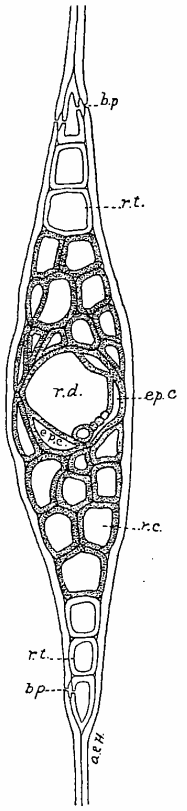


FIG. 12.—A pith ray containing a resin duct, *r. d.*, magnified 300 diameters; *r. t.*, ray tracheids; *r. c.*, ray cells; *ep. c.*, epithelial cells; *b. p.*, bordered pits.

Transverse sections of the two forms of pith rays just described, as they appear in a tangential section of the wood, are shown in figures 6 and 7. The ordinary pith ray shows 3 ray tracheids (fig. 11, *r. t.*) above and 2 below. The 5 thick-walled elements (fig. 11, *r. c.*) in the middle of the ray are pith ray parenchyma cells. The form of pith ray containing a resin duct (fig. 12) presents the same details of structure as the ordinary ray, with the addition of epithelial or resin-secreting cells (fig. 12, *ep. c.*) which line the resin duct (fig. 12, *r. d.*). The upper and lower rows of cells (fig. 12, *r. t.*) are ray tracheids, corresponding to those pointed out in the ordinary pith ray (fig. 11, *r. t.*).

QUALITY, WEIGHT, AND STRENGTH.

The wood of western yellow pine is heavy, hard, and brittle, but not coarse-grained. The sapwood resembles the eastern white pine, is easy to work, and has been widely used as a finishing material, since it is light colored and velvety. On the market it has quite a reputation as "western white pine."

According to Sargent the specific gravity of the wood is 0.4715 and the ash 0.35. Lumbermen figure the shipping weight of 1,000 feet board measure of logs to be 9,250 pounds. In October and November, however, the weight may fall as low as 8,250, and in July and August it may rise to a maximum of 10,000 pounds. Dry, sound lumber weighs from 2,500 to 3,000 pounds per 1,000 board feet.

Table 21 shows the results of tests by the Forest Service on 15 western yellow pine sills, 5 inches by 8 inches by 16 feet, cut from first and second grade common lumber about April 1. The sills were tested in bending with the load applied at two points one-third of the span from each end. At the conclusion of the bending test specimens 2 feet long were cut from the uninjured portion of each sill, and tested under compression parallel to grain. In the compression test the maximum load was the only reading taken. Crushing tests gave very uniform results. In 13 out of 15 car sills failure was due to knots. In the crushing tests 10 failures occured at knots. In all the tests the strength of air-dried material is evident.

Comparison of the bending strength of western yellow pine sills with those of Douglas fir sills of the second grade [1] gives a value of 70 for the pine on the basis of 100 for the fir. In the same way the stiffness or modulus of elasticity of the pine is 68 per cent that of the fir, and the crushing strength 74 per cent. The dry weight of the fir upon which the tests were made was 27 pounds per cubic foot, and the rings per inch about 8.

Tests made upon western yellow pine car sills were very few, and the results must, of course, be regarded as tentative.

TABLE 21.—*Results of laboratory tests on car sills of western yellow pine.*

	Green material.	Air-dry material.
Moisture.....per cent..	38.2	10.7
Rings per inch.....	12.8	11.3
Per cent of sap.....	27	.....
Specific gravity, dry.....	.38	.....
Weight per cubic foot as tested.....pounds..	32.8	27.1
Weight per cubic foot oven dry.....do....	23.8	22.4
Fiber stress at elastic limit.....lbs. per sq. in..	2,259	2,830
Modulus of rupture.....do....	3,223	4,702
Modulus of elasticity.....do....	962,000	1,311,000
Elastic resilience.....	.47	.568

[1] Three grades of Douglas fir car sills are usually designated, select, merchantable, and second.

USES.

The wood of western yellow pine is not durable in contact with the ground, and must be treated with a preservative before it can be used for ties, telegraph poles, or fence posts. Locally the chief uses are for lumber, mine timbers, lagging, stulls, and ties, The butt logs of dead trees, if thoroughly impregnated with pitch, make excellent fence posts. Settlers often use saplings for corral poles, since there is seldom a more durable species at hand. The use of wood from dead trees is becoming more extensive. A stull from a dead tree, whether sound or blued, is stronger than one from a green tree, a fact not generally recognized by mine operators. The pitchy butts of western yellow pine are often used for fuel when cedar or juniper is not available. It has been estimated that the fuel value of 1 cord of western yellow pine equals that of four-fifths cord of average oak or $1\frac{3}{4}$ cords of cottonwood.

PRESERVATIVE TREATMENT.[1]

The use of western yellow pine for construction purposes rests upon the question of its durability. As ties, poles, posts, or in other forms where the timber will come in contact with the ground and be exposed to the weather, its natural life will average only from two to four years. To increase its service to a reasonable length, therefore, the timber must be treated with chemical preservatives. The determining factors of the practicability of the impregnation of all woods are the per cent of sapwood and the degree of seasoning. The greater the proportion of sapwood the more successful will be the treatment. It is evident therefore that for poles, posts, or crossties western yellow pine is well suited for preservative treatment. The degree of seasoning will depend upon the time of felling, the method of piling, and the length of time the wood is held in storage.

It is not within the scope of this bulletin to describe the various preservative treatments in use. These are all fully treated in Forest Service Circulars 101 and 104 and Bulletins 78 and 84. Before treating any wood, however, it is necessary to inquire what will be the ultimate saving, and how this will compare with that resulting from the use of more durable species. The determining factors in answering these questions are: (1) The initial cost of the timber; (2) the cost of placement or setting; (3) the cost of treatment; (4) the life of the untreated timber; and (5) the life of the timber when treated. In Table 22 are given the comparative results from a butt and an open-tank treatment with creosote of 40-foot poles of western yellow pine and red cedar in California. Interest on the initial investment is figured at 5 per cent.

[1] Prepared under the direction of Forest Products Laboratory, Madison, Wis.

TABLE 22.—*Comparative results of preservative treatment of western yellow pine.*

Species.	Character of treatment.	Preservative, pounds per pole.	Estimated cost of treatment.	Estimated cost of poles in place.	Estimated life.	Annual cost.	Annual saving due to treatment.[1]
					Years.		
Western yellow pine.	Untreated			$8.00	3	$2.94	
Do	Brush treatment	5	$0.25	8.25	6	1,63	$1.31
Do	Open-tank treatment	60	1.90	9.90	20	.79	2.15
Red cedar				9.50	10	1.23	
Do	Brush treatment	9	.30	9.80	13	1.04	.19
Do	Open-tank treatment	40	1.35	10.85	20	.87	.36

[1] Annual saving computed from formula $a=p\frac{(1+R)^n \times R}{(1+R)^n - 1}$. a=annual saving; b=amount of initial expenditure; c=rate of interest expressed decimally.

A study of Table 22 leaves no reasonable doubt as to the economy of the preservative treatment of western yellow pine poles when only the one species is considered. In the comparison with red cedar, moreover, it is seen that under the conditions assumed the greater economy will result from the use of pine poles treated with creosote by the open-tank method.

Crossties may be considered in a like way. The average cost of all western yellow pine ties purchased by the steam railroads in 1908 was 51 cents per tie. An allowance of 10 cents for placement, 55 cents for treatment with 2½ gallons of creosote, and 13 cents for treatment with one-half pound of zinc chloride per cubic foot, gives the following cost for the tie in place in the track:

Untreated	$0.61
Creosoted	1.16
Zinc chloride	..74

Assuming a life of 3 years for the untreated tie, and figuring interest at 5 per cent, it is seen that only 7 years' service of the creosoted tie will effect an annual saving of 2 cents per tie, while but 4 years' service of the tie treated with zinc chloride is necessary to effect economy.

Whether or not greater economy will result from the use of other species can only be determined for each specific case. Under certain conditions untreated redwood ties might be more desirable; in others creosoted Douglas fir. Again, conditions may arise where a red cedar tie will be more desirable than one of western yellow pine. Wherever it is decided to use western yellow pine, however, the advantages of a properly applied preservative treatment can not be disputed.

LUMBERING IN THE SOUTHWEST.

Since there are seldom more than 2 to 4 million board feet of western yellow pine in a section, the modern steam logging of the Northwest is inadvisable in the Southwest. The usual method is to skid the logs to the hauling road, load them on the trucks, or, if the ground is fairly level, onto big wheels, and then haul them to the railroad or mill. If the operation is a large one and the railroad is in use, the logs are loaded onto the cars with a steam loader and railroaded to the mill. In one operation on the Coconino Forest, where the stand often runs from 4 to 4½ million feet to the section, a steam skidder is used, one of two in the Southwest. However, since most of the logging is by horses, an intensive system of forest management is possible.

Ordinarily a tree is cut into sawlogs up to a diameter of from 6 to 10 inches in Government sales, and from 10 to 14 inches in private holdings. In Government operations the top logs are occasionally cut into stulls, hewed into ties, or rarely split into shakes; but ordinarily the top cut is sawed into rough dimension timbers or ties. On account of the open character of the stand, very little damage is done to young growth or standing timber through lumbering.

The large companies use the latest band-saw equipment, and cut from 60,000 to 150,000 feet a day. Very close utilization of the product is secured, since they maintain box factories and manufacture laths, ties, and small dimension stuff.

The estimated cost of logging and milling over easy ground in the Southwest is:

Cutting, skidding, and hauling to railroad	$3.75
Maintenance of railroad, including ties, steel, etc	.50
Loading and hauling to mill or railroad point	1.00
Milling, including depreciation of plant and piling	4.00
Brush disposal	.40
Stumpage	3.50
Total cost of finished product on yards	13.15

As a rule the cost of logs in the mill, including the average Government stumpage rate, is between $8 and $9 a thousand board feet.

GRADES OF YELLOW PINE LUMBER OBTAINED.

The percentage of different grades of lumber cut from yellow pine varies, of course, with the locality. Table 23 gives average percentages of the different cuts which were furnished by prominent lumbermen of the region.

TABLE 23.—*Percentage of grades of rough lumber cut from western yellow pine in Arizona and New Mexico band-saw mills.*

Grades.	Northern Arizona.					Northern New Mexico, Mill No. 1.
	Mill No. 1, 1909.	Mill No. 2.		Mill No. 3.		
		1909	1907	1908	1909	
Clear	0.94	6.6	7.36	9.0	9	5.0
Select	1.03	5.8				7.0
No. 1 shop	3.39	3.5				
No. 2 shop	12.95	9.3	10.0	9.63	10	23.0
No. 3 shop	17.71	5.4				
No. 1 common	4.99	15.8	22.90	22.34	22	1.0
No. 2 common	28.22	18.0	16.42	12.0	12	21.5
Box	14.77	17.0	36.55	39.90	40	[1] 36.0
Mill culls	15.98	18.6	6.77	7.13	7	[2] 6.5
Total	99.98	100	100	100	100	100

[1] No. 3 common.
[2] Designated as No. 4, No. 5, and (culls) No. 6 common.

From Table 23 it is evident that the high percentage of grades below No. 3 shop is an important factor in any operation. These low grades must find a local market, since the high freight rates do not permit of their shipment.

An operator in northern New Mexico estimated his average grade percentages: Clear, 5 per cent; No. 1, No. 2, and No. 3 shop, 30 per cent; No. 1 common, from 1 to 5 per cent; No. 2 and No. 3 common, from 50 to 60 per cent; and mill culls, 5 per cent. The western yellow pine in this case grew in mixture with Douglas fir, white fir, and Engelmann spruce. A $\frac{3}{8}$-inch circular saw was used.

In southern New Mexico a band-saw mill that cut 15 per cent western yellow pine and 85 per cent of Douglas fir and associated species, cut the following grades in the proportions shown:

Grades.	1906	1907
	Per cent.	*Per cent.*
Selects and better	16	9
No. 1 common	25	27
No. 2 common	50	48
No. 3 common (boxing)	14	16

In 1906 a mill tally at Maine, Ariz., showed the percentages of grades cut from 112,963 board feet, by a $\frac{3}{8}$-inch circular saw, to be: Dimension, chiefly No. 1 and No. 2 common, 27 per cent; clear, 11 per cent; shop, 8 per cent; common, 36 per cent; box, 9 per cent; and cull, 9 per cent.

A still more detailed mill tally, based on 56 trees, was made in 1907 at the Dye sawmill, on the Jemez National Forest. Here also a $\frac{3}{8}$-inch circular saw was used. The results of the tally are shown in Table 24.

TABLE 24.—*Percentage of grades sawed from blackjack and yellow pine.*

Diameter.	Grade.					Dimensions, chiefly common.
	Clear.	Select.	Shop.	1 to 2 common.	3 to 4 common.	
Inches.						
13–15	.....	0.6	.....	8.1	88.1	3.2
16–18	0.6	.3	1.0	16.4	74.9	6.8
19–21	2.9	1.1	3.5	15.2	70.3	7.0
22–24	7.4	1.0	8.4	10.8	62.9	9.5
25–27	7.1	1.1	11.7	8.6	63.7	7.8
28–30	14.5	.7	17.9	5.6	43.3	18.0
31–33	15.0	1.5	21.2	7.5	54.0	.....
Average	6.8	.9	9.1	10.3	65.3	7.6

This table must be considered tentative, since it is based upon results from but 65 trees. Yet it clearly shows that increase in diameter means an increase in the percentage of the better grades. In other words, a twofold gain is made by not cutting trees of small diameter—both an increase in volume and an increase in the percentage of the better grades. The steady increase in the percentage of clears and shop is especially noteworthy. Even a tree from 19 to 21 inches in diameter cuts only 7.5 per cent clear, select, and shop, and 92.5 of common and dimension. In comparing the relative grades (clear) cut from yellow pine and blackjack, it was found that for yellow pine the average per cent was 8.4, but that for blackjack only 3.4 per cent. Table 25 shows the relative percentage of grades, including shop and better, sawed from yellow pine and blackjack.

TABLE 25.—*Relative percentage of grades (shop and better) sawed from yellow pine and blackjack.*

Diameter breast high.	Yellow pine.	Blackjack.
Inches.	*Per cent.*	*Per cent.*
13–15	.....	0.6
16–18	6.0	1.8
19–21	6.1	7.7
22–24	18.4	13.6
25–27	20.0	18.8
28–30	33.1	.....
31–33	37.7	.....
Average	20.2	8.5

MARKETS FOR YELLOW PINE.

According to the best available statistics the cut of western yellow pine in Arizona and New Mexico for the first six months of 1909 was 8,407,672 board feet and 11,540,854 board feet, respectively. If these figures are correct, it proves that at that time the timber industry had not yet recovered from the hard times of 1908, since Table 26, the result of a census collected by Forest supervisors in Arizona and New Mexico, shows that in the period between July 1, 1909, and June 30, 1910, the output increased considerably.

TABLE 26.—*Total cut of western yellow pine in Arizona and New Mexico, July 1, 1909, to June 30, 1910.*

	Saw timber.		Mining timber.		Ties.		All classes of material.		
	Sold locally.	Exported.	Sold locally.	Exported.	Sold locally.	Exported.	Sold locally.	Exported.	Total.
	Mft. b. m.	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*	*Mft. b. m.*
Arizona	18,142	43,852	652	2,398	.....	4,786	18,794	51,036	69,830
New Mexico	26,294	36,586	557	.....	7,783	.....	34,634	36,586	71,220
Total	44,436	80,438	1,209	2,398	7,783	4,786	53,428	87,622	141,050

The great amount exported is due to the large centralized cut in northern Arizona and in the Zuni Mountains in western New Mexico. The grades above No. 2 common will ordinarily stand shipment outside of the Territories. In general, a considerable amount of box material is shipped to California. The small local mills for the most part sell their entire output within the county, with the exception of the high grades, amounting to perhaps 10 per cent of the total. The 53,428,000 board feet sold locally and the 87,622,000 feet exported bring the total cut of western yellow pine in the two Territories up to 141,050,000 board feet. With the increasing sale of Government timber that is anticipated, the total cut in the two Territories should reach 150,000,000 feet by 1912.

SALE OF TIMBER ON THE NATIONAL FORESTS.

Green merchantable timber on the National Forests is for sale when its removal will not endanger the streams or reduce the timber supply below the point of safety or make a second crop doubtful. There is about 20,000,000,000 feet of merchantable saw timber on the National Forests in the Southwest. Of this, at least 80 per cent is yellow pine. Table 27 gives the approximate amount of merchantable saw timber on each National Forest and the percentage which western yellow pine forms of the stand.

TABLE 27.—*Estimate of timber on National Forests in Arizona and New Mexico.*

Forests.	Total merchantable saw timber.	Estimated western yellow pine.	Forests.	Total merchantable saw timber.	Estimated western yellow pine.
	Mft. b. m.	*Per cent.*		*Mft. b. m.*	*Per cent.*
Alamo [1]	735,000	39	Jemez [1]	2,000,000	70
Apache [2]	1,479,000	66	Lincoln [2]	181,000	70
Carson [1]	1,500,000	66	Manzano [2]	76,000	97
Chiricahua [1]	152,000	75	Pecos [2]	300,000	50
Coconino-Tusayan [2]	3,455,000	95	Prescott [2]	113,000	90
Coronado [1]	124,000	69	Sitgreaves [2]	1,500,000	98
Crook [2]	300,000	15	Tonto [1]	768,000	98
Datil [1]	2,995,000	84	Zuni [1]	401,000	87
Garces [1]	13,000	90			
Gila [1]	3,994,000	60	Total	20,086,000	.....

[1] An approximation only.
[2] Based wholly or in part on detailed ocular estimate by quarter sections.

The opportunities for purchasing Government timber are many, and conditions of logging in the Southwest tend to make such investments profitable.

There are a number of different regulations that govern the cutting of all timber on the National Forests.

Upon formal application by the purchaser the desired timber is mapped, estimated, and carefully described. When the formal application is filled out, embodying as clearly as possible the terms of the proposed contract, the timber is advertised for at least 30 days. The purchasers must submit with their sealed bids a suitable deposit to guarantee good faith, and before cutting commences a small portion of the purchase price must be paid by the successful bidder. During the sale each log is carefully scaled, numbered, and recorded. Frequent check scales are made to determine the accuracy of the Government scaler. The stipulations under the contract vary considerably, but in western yellow pine the usual conditions are, in brief: Timber can not be cut or removed until paid for, nor until scaled, measured, or counted; it must be cut from a specified area; live timber must be marked; merchantable timber used in construction is charged for; felling is done with a saw; unnecessary damage is penalized; stumps must, if practicable, be lower than 18 inches; trees must be utilized to a top diameter of 8 inches inside the bark; brush and débris must be properly disposed of as required by the Forest officers; a proportionate amount of timber must be cut each year; scaling is by the Scribner Rule, Decimal C; dead trees considered a fire menace are ordinarily felled at the expense of the purchaser; location of the cutting camps, roads, etc., is determined after conference with Forest officers; locomotives must use oil; steam skidders and donkey engines are subject to the approval of the Forest officers; and a reasonable bond is required for the proper carrying out of the contract.

In addition to green timber, all merchantable dead timber within the National Forests is for sale, except where it is needed to supply the demand of local settlers. Applications for information concerning the sale of timber on the National Forests in the Southwest should be addressed to the district forester, Albuquerque, N. Mex.

MANAGEMENT OF YELLOW PINE ON THE NATIONAL FORESTS.

GENERAL POLICY.

The chief aim of management of western yellow pine on National Forests in the Southwest must be conservatism. The marking must be conservative, the brush disposal safe, and the utilization as close as practicable. Not only must a sufficient stand be left upon the ground to protect the soil and to insure a second crop, but a supply

of timber must in the future be available for purely local industries. Waste by private owners, even if it amount to only 5 or 10 per cent of their total cut, will mean a shortage in the future timber supply of the Southwest.

In managing western yellow pine, therefore, it is essential that provisions be made for a sustained annual yield. This does not mean, however, that only the annual growth will be cut. In the average virgin forest growth is offset by decay. Most of the stands on the national forests in the Southwest are virgin, and consequently the mature timber that goes to waste each year is a great loss. It is true that this natural loss is offset theoretically by the growth of new stands, but full use is not made of the forest unless the mature timber is cut and the thrifty growing immature stands left for future needs. Moreover, it is the desire of the Forest Service not only to maintain a sustained annual yield, but to improve the quality of the timber as well. If only timber of the lower grades is produced, export shipments will suffer. It is therefore particularly essential, on account of the long hauls and consequent heavy freight rates, that a fair proportion of higher grades be supplied. Yet the Forest Service is bound to dispose of all over-mature timber, and if this is done the annual cut must be more than the estimated annual growth of the normal forest. It will be necessary not only to dispose of the annual growth, but also to reduce the excess growing stock represented by virgin stands. For instance, if there were 100,000 acres, every one fully stocked to its full capacity, under normal conditions it might be the duty of the Forest Service not only to cut the actual annual increment, but also to reduce the excess growing stock to what would be considered normal—in this case one-half the present mature stand.

METHOD OF CUTTING.

The regulation of the cutting of western yellow pine depends upon the method of cutting, which in turn must be governed by the silvical requirements of the species. In the past the cutting in Government timber sales has removed about two-thirds of the stand. Wherever possible, the one-third left standing has been selected from thrifty blackjack, though frequently it has been necessary to retain mature trees. It is planned to return and cut this one-third of the original stand as soon as reproduction is complete. It is not known how long the reproduction period must last, but probably 15 years, and perhaps 20, will pass before satisfactory regeneration takes place. The present method of cutting might be termed a group selection, or a primitive application of the shelter-wood (femelschlagbetreib) system applied to irregular stands. At all events, the idea has been to prepare for a second crop by cutting two-thirds of the original stand, and when the new crop is established to cut the remainder.

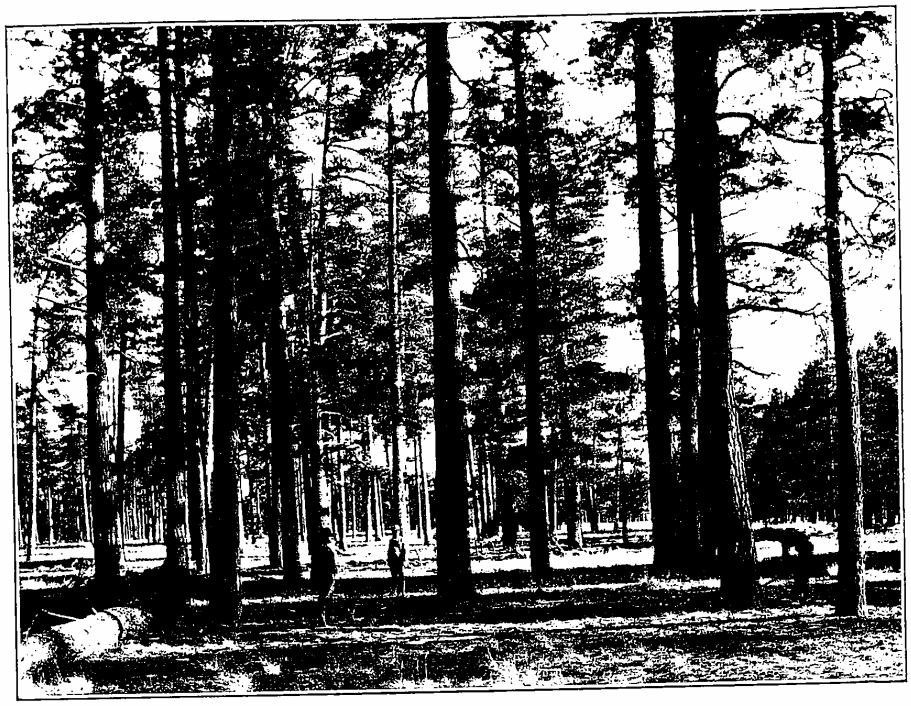


FIG. 1.—FULLY DEVELOPED MATURE STAND OF WESTERN YELLOW PINE BEING MARKED FOR CUTTING.

FIG. 2.—THRIFTY "BLACKJACK" LEFT AFTER CONSERVATIVE LOGGING.

MARKING THE TIMBER.

Ordinarily all mature and over mature western yellow pine should be marked, except when required for seed or protection, since they have practically stopped growing. Similarly, all trees which show such defects as punk knots, spike tops, bad crooks, low forks, and injurious fire scars should be marked for cutting. Even an approximate diameter limit should be flexible. Young, thrifty, rapidly growing trees should not be marked, even if larger than the stated diameter. Defective trees of any usable size should be marked unless there are technical or practical objections.

At least one-third of the stand should be left to reseed the area, provide a second cut, and protect the soil. No ironclad rule, however, can be made that will apply to all conditions; consequently the amount left standing should be varied according to local requirements. The economic need of an early second crop should have weight.

Where the danger of windfall is great, but few trees should be marked for cutting. This rule would also apply where a dense forest cover is needed for the protection of a watershed or to prevent erosion. The probable harm from too heavy marking on all slopes and in exposed situations must be carefully considered. Each tree left should have its crown free enough for vigorous growth. If usable, trees which have been badly grouped and have only small, sickly crowns should be marked, unless needed to preserve proper soil conditions.

Where there are not enough young trees to form a good stand in the future seed trees must be left. These should be thrifty and capable of bearing large quantities of seed at once. Occasionally it will be necessary to retain seed trees too misshapen or defective to be merchantable, but as a rule young trees which will yield good lumber in the future should be chosen. Where western yellow pine is growing in mixture all seed trees should be of the more valuable species, but poorer species are better than none. In situations where logging is difficult the practicability of logging individual trees should be considered.

Fewer seed trees should be left where partial reproduction is already established than where there are no seedlings, yet if there is danger that fire will run over the area enough trees should be left to seed the ground fully, whether reproduction is present or not. Large openings should not be made or small openings enlarged where the future forest will suffer. Seed trees should always be left on the edge of openings, such as old burns, on the side from which the prevailing winds blow. On ridges and along the edges of parks it is usually advisable to mark very conservatively.

It often happens that some dry-topped and diseased trees which can and should be removed are overlooked in the original marking. It may also be advisable to reserve seed trees that were originally marked. Necessary changes in the first marking should be made before the sawyers have moved away. It is only by a careful remarking that undesirable trees can be completely eliminated and necessary seed trees retained.

In marking timber a simple rule to remember is: Mark most yellow pine and leave all healthy blackjack except when in need of thinning. This rule should be varied according to the age and condition of the stand marked. If the timber is mature, with no reproduction, it may be necessary to retain trees that are fully mature, and approximately one-third of the volume may have to be left standing, even at some risk of windfall and decline in vigor. In a mature stand with good reproduction the marking may be heavier, but sufficient trees should be left to provide for reproduction in case of fire. The marking should aim to open up the reproduction and enable each group to enlarge. It should also tend to improve the stand by removing dry-topped or otherwise deteriorating trees. In a pole stand of blackjack thinning can often be made to advantage, but these should never be heavy and should aim to preserve a close canopy. Trees which should be removed are those that are deteriorating and which may be eventually suppressed.

In marking any sale area innumerable variations will be encountered, and no uniform system should be adopted for the entire stand. On the border of the woodland type the marking should be merely an improvement cutting, and if the stand is less than 2,000 feet per acre no cutting whatever should be allowed, except the occasional removal of dying trees, and this only if practicable from a lumberman's standpoint. On the borders of parks and where windfall is likely, or where it is desirable to preserve forest conditions, marking should be particularly conservative. On dry south slopes and on ridge crests but a few trees should be removed. Ordinarily in western yellow pine an approximate diameter limit of 20 inches should be stated, though not followed literally in the marking, as already explained. Wherever practicable advantage should be taken of good seed years to increase the cut or to direct the marking where the local seed crop is best. The scenic value of timber along roads must be carefully weighed.

Table 28 shows the actual results of marking on a large timber sale area in the Coconino National Forest. Figures are given for each section, in order to show how uniform the cutting has been. The windfall on seven sections was, respectively, 0.7 per cent, 0.2 per cent, 0.6 per cent, 0.2 per cent, 0.8 per cent, 0.3 per cent, and 0.8 per cent of the stand from one to two years after cutting. This loss was almost

entirely in mature timber. The damage from lightning was also considerable.

TABLE 28.—*Results of cutting on Greenlaw Lumber Co. sale, Coconino National Forest.*

Location.	Number of acres.	Average cut.	Average amount left standing.	Per cent of original stand left.
		Ft. b. m.	*Ft. b. m.*	
T. 21 N., R. 8 E., sec. 3	396	3,350	1,294	27.9
T. 21 N., R. 8 E., sec. 5	229	3,590	1,330	27.1
T. 21 N., R. 8 E., sec. 6	238	3,246	1,060	24.6
T. 21 N., R. 8 E., sec. 7	310	2,228	1,339	37.5
T. 22 N., R. 8 E., sec. 29	211	2,105	1,240	37.1
T. 22 N., R. 8 E., sec. 30	160	3,125	1,521	32.8
T. 22 N., R. 8 E., sec. 31	195	3,069	1,020	24.9
T. 22 N., R. 8 E., sec. 32	622	3,550	1,349	27.5
T. 22 N., R. 8 E., sec. 33	434	5,645	1,422	20.1
T. 22 N., R. 8 E., sec. 34	590	5,302	1,493	21.9
T. 22 N., R. 8 E., sec. 35	610	2,571	1,152	30.9
T. 22 N., R. 8 E., sec. 26	60	2,760	1,418	33.9
T. 22 N., R. 8 E., sec. 27	126	2,998	1,579	34.5
T. 22 N., R. 8 E., sec. 28	370	2,886	1 500	34.2
T. 22 N., R. 8 E., sec. 15	310	5,376	1,898	26.0
T. 22 N., R. 8 E., sec. 21 E. ½	275	3,489	1,449	29.3
T. 22 N., R. 8 E., sec. 23	73	1,876	1,556	45.3
T. 21 N., R. 8 E., sec. 9	160	3,955	1,372	25.9
Average	.....	3,395	1,388	30.0

Cutting on private land in the Southwest is usually in decided contrast to that on the National Forests. On all private land within the Tusayan National Forest logged north of Challender the average stand left per acre amounted to but 699 board feet. About 300 feet, board measure, of merchantable timber was left on the ground through wasteful logging.

ROTATION OF CUT.

The best rotation for western yellow pine can not be predicted with certainty until regulated cutting has been more thoroughly tried out. Tentatively, a rotation of 200 years is recommended. The average mature blackjack is from 125 to 150 years old. Ordinarily the overmature yellow pine which is now being lumbered is from 300 to 400 years old. All available figures indicate that it will take 200 years to grow saw timber. It will be seen from the preceding tables that diameter growth begins to fall off at from 100 to 160 years, and that height growth declines from the mean annual after 170 years. In Table 10 a yellow pine 200 years old averages only 20.60 inches in diameter, and in Table 11, 21.3 inches. This is certainly the minimum size that can be estimated to yield timber of fair quality that will justify shipment. With thrifty, well-thinned stands, however, it is hoped the growth will be greater.

In some localities approximately 1 per cent of the total growing stock is believed to be a safe annual cut. This figure will, of course,

vary with local conditions. It is justified by Van Mantel's method of regulating the yield, in which the growing stock, divided by half the number of years in the rotation, is the annual cut. This method tends to reduce automatically the excess growing stock to normal, and to increase the growing stock where it is dangerously low. The Austrian method of regulating the yield may also be followed. By this the annual cut is equal to the mean annual increment, plus the difference between the real growing stock and the normal growing stock, divided by the period during which the surplus is to be removed. The normal growing stock in turn is determined by multiplying the mean annual increment by half the rotation. The chief difficulty in applying this method in the Southwest is the lack of exact information regarding annual growth after cutting. Steps have, however, been taken to secure accurate data, which should be available within 10 years.

On some Forests empirical methods of limiting the cut may be adopted. For instance, where a certain area is to be cut on a 200-year rotation, it may be assumed that the stand on one two-hundredths of the area could safely be cut each year, provided regeneration follows. Whatever the method employed, the object is to limit the annual cut so that a sustained annual yield is possible.

FIRE PROTECTION.

During the year 1909 a total of 91,895 acres were burned over on the 19 National Forests in Arizona and New Mexico. It is remarkable that the total damage to timber on the entire area amounted to only $73,971. If the Gila National Forest were omitted, the total damage to timber on the 18 other Forests would amount to only $21,471. The damage on the Gila, amounting to $52,500, was the result of extraordinary conditions of drought and of the lack of settlement in the region, which made it exceedingly difficult to secure quick assistance in fighting the flames.

The total number of fires which gained headway in Arizona and New Mexico in the calendar year of 1909 was 259. The causes of these, as far as it has been possible to ascertain, were:

Cause:	Number.
Unknown	108
Campers	69
Lightning	33
Railroad	12
Sawmills	9
Brush burning	7
Incendiary	4
Miscellaneous	17
Total	259

The best preventive measures are a careful and efficient patrol and the education of the public to the destructiveness of forest fires. In the open western yellow pine forest fire lines are seldom necessary, but where reproduction is present it is advisable to burn the débris resulting from timber sales after it has been piled. Where, in order to secure natural reproduction, it is necessary to risk brush scattering, it would undoubtedly be advisable to burn fire lines bisecting the area, if possible, at least 300 feet in width. If the fire danger is particularly great, the line should be burned over every year. This would, of course, mean a large expense. Ordinarily, back firing is possible without regular fire lines, providing dry débris resulting from logging has previously been cleared and burned. With brush scattered on the ground and a high wind it is almost impossible to stop a fire until the wind subsides. Dead snags are a particular menace in fire fighting, and the following clause is now being inserted in all timber-sale contracts:

> All dead standing trees considered a fire menace by the Forest officer in charge will be felled; but only such portions of them as are merchantable under the terms of this contract will be logged and paid for. This does not include black-jack nor stubs too small to be merchantable under the contract.

In order to ascertain the cost of such a provision, the dead trees on a representative area of 640 acres were felled. The actual cost of the operation was 0.024 cent per thousand board feet of dead trees.

Watch towers, lookout points, telephones, trails located along ridges, and roads cleared of pine needles are of great assistance in locating and combating fires. Engines operating on National Forest land should burn oil, but if coal or wood burning engines are permitted, an efficient spark arrester should be insisted upon. Since the average spark arrester is far from efficient, railroads passing through National Forests should, in addition, be compelled to clear their right of way annually of all inflammable material, and, if necessary, maintain a patrol to follow each train. Fire tools should be available at convenient points. After a fire is under control a sufficient guard should be maintained to put out additional fires set by smoldering logs, or that break out in any other way.

DISPOSAL OF BRUSH.

As a general rule brush from western yellow pine should be scattered, except where there is danger of fire, or where the timber is dense or reproduction present. The brush should be scattered thickly enough to afford actual protection. A cover of brush apparently dense when green will, when it dries out and the needles drop off, give little protection against the sun and wind. Occasionally in openings where it is necessary to keep cattle or other stock away from

existing or expected reproduction, the brush may be merely left as it falls. Ordinarily, the brush should be lopped so as to lie not higher than 2 feet above the ground. Brush disposal should always keep pace with logging.

Where the fire risk is great all lops and débris, including large chips, should be piled at a safe distance from standing trees. The piles should be large and compact enough to kindle easily and burn cleanly. Brush should not be piled on stumps, large tops, or unmerchantable logs, nor in groups of seedlings or young growth, or against dead snags. Whenever possible, the brush should be piled in openings with all branches lopped from the tops placed together with those cut from the logs. The trimmed tops and large branches should be left where they lie, and should not be covered by brush piles. Where there are no large openings and the brush must be piled near living timber, the piles should be small.

Brush burning is necessary wherever there is danger of fire. Ordinarily, however, it is not advisable over an entire sale area. It is frequently possible to burn the brush so as to form fire lines, especially along railroads and wagon roads. Fire lines through brush should ordinarily follow ridges rather than canyons, and should be laid out according to the topography rather than by section lines. Where to burn brush completely would result in damage to existing reproduction, or would be destructive to sound seed, unburned piles should be left, unless the fire danger is excessive. The effect of burning on grazing and future reproduction should be carefully considered. The best time to burn brush is after a slight fall of snow, or early in the spring before the snow has melted, or during or immediately after summer rains. In insect infected areas brush should be burned, if the pupa can thus be destroyed. The débris from fungus-infected trees should be burned, but not necessarily that from trees infected with parasites such as mistletoe.

COST OF HANDLING GOVERNMENT TIMBER SALES.

An objection often raised against conservative methods of forest management is that their cost is excessive. It has been claimed by some lumbermen that to log western yellow pine conservatively entails an extra cost of from 75 cents to $1 per 1,000 board feet. In considering the question of cost it should be borne in mind that from 40 to 50 per cent of the added expense is chargeable directly to the cost of brush disposal, which is often an essential operation if the future stand is to be safeguarded against fire and reproduction secured. The cost of supervision on Government timber sales in the Southwest varies, of course, with the size of the sale and the local difficulties of

administration. An estimate based on past experience shows the cost per 1,000 feet board measure, under favorable conditions, to be:

Examination of sale	$0.02
Marking	.04
Scaling	.15
Brush burning	.03
General administration	.10
	.34

Assuming that 34 cents is an average figure for operations of any magnitude, it does not seem an excessive figure to pay for conservative management, including scaling. A private company could probably supervise conservative logging on a very large operation for a less amount.

REFORESTATION.

As already explained, with a reasonable number of seed trees, under favorable conditions of soil and moisture, natural reproduction of western yellow pine is almost certain. Where timber is cut from a stand already overmature, and the danger from windfall, fungus, and insects makes it impracticable to leave seed trees, planting or sowing will eventually be necessary. Between 4 and 5 per cent of the total area of the National Forests in Arizona and New Mexico, or approximately a million and a quarter acres, will require more than a hundred years to restock naturally, and in consequence should be planted artificially. In addition to areas covered by timber sales, there are small parks, blanks, and openings that eventually may be planted. The most favorable situations will probably reproduce naturally, and sowing or planting will, therefore, be done on sites not altogether favorable. An exception might be made in the case of a large burn, where it is not thought advisable to wait the necessary length of time to secure natural reproduction, or on timber-sale areas where reproduction is slow in coming in.

The problem of artificial reproduction in the Southwest is made difficult by the unfavorable climatic and soil conditions that will undoubtedly have to be met. Judging from the results in the Karst, in Austria, unfavorable sites can be reforested only by planting thrifty stock with well-developed root systems. Though the long tap root of the western yellow pine makes planting especially difficult and expensive, it is at the same time peculiarly well adapted to withstand the drying out of the surface soil. Recent experiments have indicated that 2-year-old seedlings can be planted successfully on favorable sites, though this success may only be temporary. It is possible that planting can never be entirely successful unless it is done on carefully prepared ground and the young trees given proper protection.

SEED COLLECTION AND EXTRACTION.

Before sowing or planting on a large scale one of the most important steps is to secure for a reasonable cost seed of good germinating power. The cost per pound of collecting and cleaning 1,335 pounds of seed on the Coconino National Forest in 1908–9 was as follows:

Gathering cones	$0.576
Drying and separating	.201
Cleaning	.046
Equipment	.086
Total	.909

Later, in 1909, the total cost of securing seed on the Coconino Forest was reduced to 53.3 cents a pound, due to the opportunity which was presented of collecting seed where logging was in progress.

At elevations of approximately 7,000 to 7,500 feet on rolling mesa land the collection of western yellow pine cones may usually be begun on September 20 and continue until November 10. To collect economically it is necessary to establish a regular seed-collection camp, and have a large crew of men to push the work rapidly. The best time for collecting the seed is when the cones are beginning to turn brown, but before they commence to open. On any area where lumbering operations are in progress the cones can be secured very cheaply without interfering with the logging. The cone should be removed from the tree as soon as it is filled; otherwise they may open and considerable seed be lost. Occasionally it is practicable to collect western yellow pine seed from squirrel hoards. Two-bushel sacks are convenient for collecting purposes, but care should be taken that needles and débris are not mixed with the cones. To allow for expansion the sacks should be only half filled. When the cones are gathered and sacked they should be hauled to the camp and spread out on the drying rack with free air circulation around and through each sack, which should be shaken thoroughly once a day. Should a storm come up during the drying process, the sacks should be covered, since if the cones absorb moisture drying will be materially delayed.

To separate the seed from the opened cones, a box 4 by 4 by 3 feet on an axis suspended from a wooden frame should be constructed. Two sides of the box should have numerous one-fourth to three-fourths inch holes through which the seed can sift when the box is turned. The box should be protected from the wind and provision made for the seed to drop onto a canvas underneath. As the cones open farther they should again be churned until all the seed is extracted. When dry, about 15 pounds of seed at a time should be placed in a washtub and tramped until the wings have

FIG. 1.—CLOSE UTILIZATION. TOPS CUT FOR MINE PROPS.

FIG. 2.—STANDING DEAD TIMBER; A WASTE AND A FIRE MENACE.

been separated. The seed is then run through a grain fanning mill until it is thoroughly clean. It is then sacked and stored, preferably in air-tight earthenware jars, in a dry, cool, rat-proof building, until ready for shipment.

The germinating vigor of the western yellow pine collected has varied considerably. In 1909 samples from the Coconino National Forest were 82 per cent sound; in 1910 seeds from the same Forest germinated 63 per cent in a soil test of four weeks' duration. According to tests made in 1907, germination of seed collected on the Pecos National Forest averaged 73 per cent at Halsey, Nebr.; 75 per cent at Pasadena, Cal.; and 85 per cent in the laboratory at a temperature of 77° F. Examination of the seed showed 1,300 to the pound and 500 to the pint. One pound would sow 200 linear feet of seed drill, and one pint 90 feet.

NURSERY PRACTICE.

Western yellow pine nurseries should aim to produce thrifty transplants, 2 or 3 year old stock, provided the cost of production can be kept low. Broadcast sowing in seed beds gives the best results. The beds should be graded so that the center of each may be slightly higher than the sides to provide for irrigation and drainage. One pound of western yellow pine seed, with a germination per cent of from 60 to 80, is sufficient when broadcasted for 48 square feet of seed bed, allowing 100 to 150 seedlings to the square foot. The beds should be mulched during germination in order to conserve the moisture and yet transmit heat. Burlap is excellent for the purpose. Where seedlings are heaved or lifted by frost the beds should be mulched during the winter months. Sowing should be done between April 15 and July 15. Early sown seedlings are larger and hardier, and less likely to be winterkilled. A system of low shade frames with wire netting to exclude birds and animals is satisfactory.

Nursery experiments conducted at the Gallinas planting station on the Pecos National Forest indicated that April sowing gives better results than March or May. The best root pruning was secured by making an artificial hardpan from 8 to 12 inches below the surface. Seed beds gave better results when mulched after sowing, but a lighter mulch of needles should be substituted when germination begins, followed by moderate watering. Low shade frames were best, particularly when the danger from rodents was great. Seed did well on all soils, but burned a little on pure sand. Damping-off was stopped by removing the shade, by sanding the seed beds, and by cutting off the water supply. At another time it was eradicated in 24 hours by spraying with Bordeaux mixture. It was found that heeling-in transplants over winter prevented loss by throwing.

FIELD SOWING AND PLANTING.

There are three different seasons when planting is possible; spring, just before the summer rains, and just before the winter snows. There are indications that each of these seasons is the most favorable time, though there seems to be an inclination toward planting before the summer rains. Winter losses from summer planting have been severe. Probably spring planting will in the long run be the most successful.

Planting of thrifty stock with well-developed root systems seems to be the only successful method, except in very favorable sites on high elevation, where direct seeding promises success. Where sowing is attempted, careful soil preparation and some protection against adverse climatic conditions are essential. Systematic poisoning of rodents is also often necessary.

Cool northern or eastern exposures where moisture conditions are most favorable, or a partially protected draw at moderate elevations, are the best planting sites. The stock planted should, if possible, be raised fairly near the site, and should consist of 2-year-old transplants, except in favorable situations, where natural seedlings may be used. Ordinarily the pit method is best, with a spacing of 5 by 5 feet, care being taken to select the most protected places for each spot. It is essential that the surface of the hole should be slightly below the rest of the land, and that protection be given transplants while being planted.

Western yellow pine when broadcasted should be sown about 6 or 8 pounds per acre on the basis of 70 per cent germination in prepared soil. Poisoned wheat or other grain should be scattered where rodents are numerous. Perhaps the cheapest method would be to sow on the ordinary soil where the grass is not thick, and either rake or harrow the seed in. A crude brush rake will often give the desired results by wounding the soil. The cost of sowing western yellow pine broadcast will seldom amount to less than from $10 to $12 per acre, depending upon the cost of the seed. There is a general impression that but a few pounds of seed are necessary in sowing. On the contrary, to be successful artificial sowing must be lavish, yet there is danger of going to extremes in the matter. Thus in seed-spot sowing, even with seeds of a comparatively low germination per cent, from 10 to 15 seeds to the spot will furnish at least one or two seedlings, provided any germination at all takes place. When a much larger number of seeds are sown, the seedlings often come up in a dense mass, and so do not stand as good a chance as if there were only one or two seedlings with correspondingly less competition. Moreover, rodents are attracted to a greater degree. In seed-spot sowing, as well as in planting, it is hightly important that the loca-

tion of each spot be selected with care. Another important point in direct seeding is the necessity for firming down the surface of the soil where any preparation is given it. If the soil is loosened up and the seed sown merely on the top of it without being pressed down, the surface layer of the soil is likely to dry out and make it impossible for the seed to germinate or for the seedling to get a start should germination take place. The seed should not, of course, be pressed too deep into the earth, but should merely be stepped on and the soil pushed into place. The important point in seed-spot work is to clear away a sufficient area of sod and other vegetation that would be likely to choke out the young seedlings, and then to bring the seed sown into close contact with the firm mineral soil. There is also danger of sowing the seed too deep, especially where furrows are plowed and the seed sown either on the bottom or side of the furrow. The danger is that the soil on the side of the furrow will wash down and either cover the seed so deep that it will not germinate or else bury the seedling after it has got a start.

OTHER SOURCES OF INCOME.

In addition to furnishing timber, the western yellow-pine forests offer range for horses, cattle, and sheep. The grass within the western yellow-pine type is above the average quality, yet it takes at least 8 acres to support 1 sheep and 40 acres for each horse or cow. It must be remembered, however, that both cattle and horses usually run over the same area within the limits of the western yellow-pine type. The average yearlong fee is 12 cents for sheep, 35 cents for cattle, and 40 cents for horses, or approximately 1 cent per acre per year for each class of stock.

Seed from western yellow pine will readily sell for $1 a pound, but as yet this industry has not been developed. There is but one commercial seed collector in Arizona and New Mexico.

There is no evidence that western yellow pine has been tapped for resin in the southwestern United States; yet during the Civil War it was successfully boxed in Butte[1] and Tehama Counties, Cal., while the high prices prevailed. After the war operations ceased. Extensive commercial operations with this species are carried on at Madera, Chihauhua, Mexico.[2] In August, 1910, turpentine experiments were started on the Coconino Forest.[3] Ninety trees were boxed and hung with 190 cups, under a cup system. The first streak was put on August 3, the first dipping was made on August 24, and the last dipping on September 14. The two dippings yielded 272

[1] E. A. Sterling, Forest Conditions in the Sierras, 1906.
[2] Reported by W. D. Sterrett, Forest Service.
[3] H. S. Betts, Turpentine Experiments on Western Yellow Pine, preliminary report in manuscript, 1910.

pounds of crude gum. Mr. Betts's deduction is that this is equal to an average of 23 barrels of dip at each dipping, to a crop of 10,000 cups; the average yield on the Florida National Forest is 25 to 30 barrels. Further experiments will begin earlier and be on a larger scale, but the results this far indicate that the amount and quality of turpentine and resin does not differ greatly from the average of the Southeast.

CONSERVATIVE LUMBERING ON PRIVATE LANDS.

The common question of the lumberman operating in yellow pine, "Will it pay me from a financial standpoint to practice forestry," can be answered in the affirmative. Just how much it will pay will depend, of course, upon the conditions under which each individual lumberman operates. The lumberman's chief loss is undoubtedly through fire. Manifestly, then, it will pay him to protect his timber from fire and to use reasonable precautions in his logging operations. To burn oil in his engines and to see that his steam skidders and donkey engines are provided with suitable spark arresters may be the means of preventing large and irreparable losses. Close utilization is undoubtedly wise from a financial standpoint. While the lumberman may not care to work his trees to a 6 or 8 inch top diameter unless the product can be marketed for small stulls, narrow-gauge ties, lagging, and the like, it would certainly be profitable to cut western yellow pine to a top diameter inside the bark of from 8 to 10 inches. Dead timber can be closely utilized, and one of the largest manufacturers in Arizona is now doing this. The loss from waste in the woods is often ignored, since by permitting waste the cost of logging is slightly reduced. A loss of 10 per cent on the original product will decrease the life of a manufacturing establishment and take away 5 years from a 50-year undertaking, while the cost of equipment must be distributed over 45 years instead of 50, a factor to be reckoned with in considering profits.

A problem which always confronts the owner of private land is whether to log it clean or leave enough timber on the ground for a second cut. Manifestly, a small tree yields a disproportionately small amount of lumber. A yellow pine 28 inches in diameter breast high, cutting four 16-foot logs, scales 950 board feet, while a blackjack 14 inches in diameter breast high scales but 70 feet and will yield nothing but a few ties, a couple of stulls, or a knotty saw log. By comparing the volumes of the two trees it is apparent that that of the 28-inch tree is more than 13 times greater than that of the 14-inch tree, though the diameter of one is only double that of the other. Small timber, moreover, yields products of poor quality and costs more to log and to saw at the mill. Consequently, the lumber-

EXICO.

is equal to
p of 10,000
is 25 to 30
on a larger
nd quality
average of

DS.

ellow pine,
forestry,"
l pay will
individual
doubtedly
his timber
ng opera-
skidders
sters may
s. Close
t. While
inch top
ulls, nar-
profitable
of from
ne of the
oss from
aste the
t on the
stablish-
hile the
d of 50,

land is
d for a
ionately
r breast
black-
nd will
aw log.
at that
of the
of the
ty and
umber-

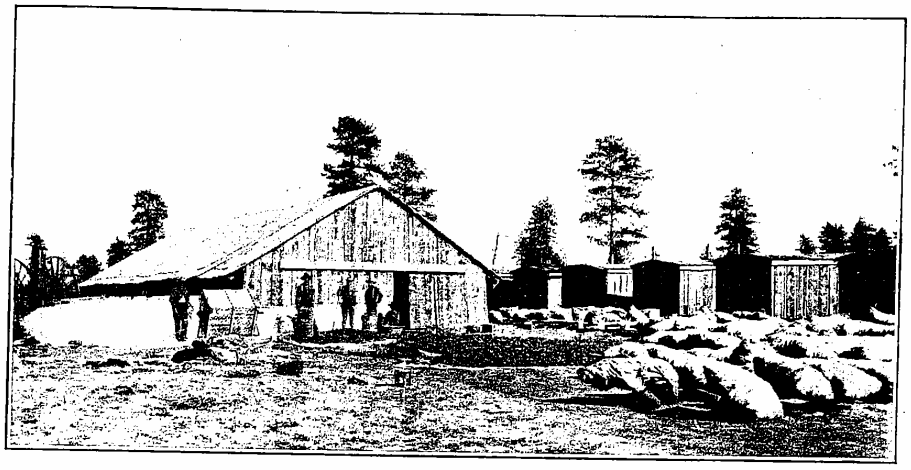


FIG. 1.—EXTRACTING WESTERN YELLOW PINE SEED AFTER DRYING.

FIG. 2.—WESTERN YELLOW PINE SEEDLINGS KILLED BY SHEEP; SALTING GROUND NEAR WATER, PRESCOTT NATIONAL FOREST.

man with an eye to the future may reasonably plan to leave the small timber and return in 20 years to relog when the young stand has increased from 40 to 65 per cent in volume. Trees left after logging with plenty of light for their crowns will increase rapidly in diameter.

The private timber owner to secure best results should remove trees that are deteriorating in value, since these will not increase in volume and will decrease in quality. Reproduction must be protected. Experience in New England has shown that forest land without merchantable timber, but fully stocked with reproduction, has a much greater sale value than land absolutely denuded. The steady development of the Southwest assures a strong local market for the conservative operator who gets his present profit out of the mature and overmature stands and reserves his thrifty young growth for the future.

In New Mexico cut-over tracts may be assessed as grazing lands at 25 cents per acre. The average tax rate on this class of property is estimated at 4 per cent, or 1 cent per acre per year. Assuming that 2,000 board feet of timber is left per acre, this means, at a stumpage rate of $2.50 a thousand, an investment per acre of $5. If this land is held for from 10 to 20 years, what will be the cost and the profit? A reasonable charge for fire protection is 1 cent per acre per year. It will be much greater than this immediately after logging, but when the needles and débris have rotted, an efficient patrol, with occasional expenses for fire fighting, will mean but a small annual cost distributed over a wide area. From experience elsewhere stumpage is bound to increase in value. In Maine stumpage values have increased $1 per 1,000 board feet per decade, and in a newly settled country such as the Southwest, a future stumpage price of $4 in 10 years and $6 in 20 years seems a conservative estimate. Placing the interest at 5 per cent, compounded annually, fire protection at 1 cent per acre, land valuation at 25 cents, taxes at 4 per cent per annum, present stand 2,000 feet, valued at $5, initial expenses at 10 cents per 1,000 board feet, stumpage at $4 in 10 years and $6 in 20 years, and growth at 10 per cent per decade, the total cost and sale value would be as follows:

Present valuation	$5.00
With initial expense	5.20
In 10 years:	
Total cost	8.72
Sale value	8.80
In 20 years:	
Total cost	14.46
Sale value	14.40

Under total cost is included all annual expenses and taxes compounded at 5 per cent, so that it will be seen that the investment has

netted almost exactly 5 per cent on the capital. If the shortage of lumber becomes as great as freely predicted, stumpage values will be much higher than those just given and the profits in consequence much greater. Changes in the present method of taxation to one in which a tax will be levied only on the final output would also materially increase the net returns. In addition to the revenue from the timber, most tracts can be leased for grazing during the 20 years between the first and second cuts and a substantial revenue secured from this source.

SUMMARY.

Western yellow pine in the Southwest does not reach the development attained on the Pacific coast. Yet it is a tree admirably adapted to the semiarid conditions of the region and is capable of yielding excellent saw timber. It withstands disease well and except in early life is not especially susceptible to fire, drought, frosts, or snow. Its growth is slow; from 160 to 200 years are usually necessary to produce a saw log. The better grades of lumber are excellent for finish, and with preservative treatment the wood is durable in the ground. Lumbering in the Southwest is expensive, chiefly on account of the high price of labor. The higher grades of lumber are easily disposed of, but the lower grades are difficult to market. Nevertheless the timber on the National Forests in the Southwest offers excellent opportunities for investment. A conservative method must be adopted upon the National Forests, and it appears essential that the cut should be regulated, either by volume or by area, upon the basis of a 200-year rotation.

Western yellow pine yields excellent resin and turpentine, which may become of commercial importance as by-products.

While fire lines are not essential, an efficient patrol is an absolute necessity. Where natural regeneration fails artificial reforestation will be necessary. Sowing is preferable, but where impracticable transplants or seedlings may be set out.

The private owner can well afford to protect his holdings from fire, to insist upon a close utilization of the product, to plan for a second cut, and to adopt many of the conservative methods of lumbering used on the National Forests. By doing this he may reasonably expect a 5 or 6 per cent return upon his investment, plus the rental value of his land for grazing purposes during at least a portion of the time.

APPENDIX—VOLUME TABLES.

The tables which follow are based upon volume analyses taken on the Tusayan Forest in 1905 and 1906. Tables 29 and 30 are based upon diameter breast high, but the height of the trees through which the measurements were taken is indicated in used length. These two tables are distinctly local, and will not give accurate results unless the timber is of the same height as that which formed the basis of the tables. Tables 31 and 32 will be found accurate for any western yellow pine stand in the Southwest. Accurate local volume tables based upon diameter alone may be constructed by measuring the diameter breast high and total height or total merchantable length, and after determining the average height of trees of each diameter, read the average volume from either Table 31 or Table 32.

TABLE 29.—*Volume of blackjack in board feet (Scribner decimal C rule) on basis of diameter.*

Diameter breast high.	Volume (board feet).	Used length.		Basis, trees.	Diameter breast high.	Volume (board feet).	Used length.		Basis, trees.
		Feet.	16-foot logs.				Feet.	16-foot logs.	
Inches.					*Inches.*				
10	30	.....	.....	.....	23	400	47	3.0	34
11	40	.....	.....	.....	24	450	49	3.0	27
12	50	.....	.....	.....	25	520	51	3.0	19
13	60	20	1.0	16	26	580	53	3.5	10
14	70	22	1.5	80	27	640	55	3.5	6
15	90	25	1.5	153	28	700	56	3.5	5
16	110	29	2.0	161	29	760	57	3.5	.....
17	140	32	2.0	125	30	810	59	3.5	4
18	180	35	2.0	116	31	870	60	4.0	1
19	210	38	2.5	64	32	930	62	4.0	2
20	250	41	2.5	46	33	980	.....	.....	.....
21	300	43	2.5	34					928
22	340	45	3.0	25					

TABLE 30.—*Volume of yellow pine in board feet (Scribner decimal C rule) on basis of diameter.*

Diameter breast high.	Volume (board feet).	Used length.		Basis, trees.	Diameter breast high.	Volume (board feet).	Used length.		Basis, trees.
		Feet.	16-foot logs.				Feet.	16-foot logs.	
Inches.					*Inches.*				
10	40	.....	.....	.....	29	1,020	64	4.0	57
11	60	.....	.....	.....	30	1,140	66	4.0	44
12	70	.....	.....	.....	31	1,270	68	4.5	26
13	90	27	1.5	22	32	1,410	69	4.5	28
14	110	32	2.0	47	33	1,560	71	4.5	22
15	130	35	2.0	93	34	1,730	73	4.5	21
16	160	38	2.5	119	35	1,910	75	4.5	17
17	190	41	2.5	142	36	2,080	76	5.0	12
18	230	43	2.5	140	37	2,220	78	5.0	6
19	270	45	3.0	138	38	2,330	80	5.0	4
20	310	47	3.0	108	39	2,430	81	5.0	5
21	360	49	3.0	128	40	2,520	83	5.0	2
22	420	51	3.0	138	41	2,610	.....	.....	.....
23	480	53	3.5	102	42	2,700	.....	.....	.....
24	550	55	3.5	109	43	2,790	.....	.....	.....
25	630	57	3.5	88	44	2,880	.....	.....	.....
26	710	59	3.5	95					1,863
27	800	61	4.0	85					
28	910	62	4.0	65					

TABLE 31.—*Volume of yellow pine in board feet (Scribner decimal C rule) on basis of diameter-height, in feet.*

Diameter breast high.	Height of trees.									Diameter of top inside bark.	Basis, trees.
	40 feet.	50 feet.	60 feet.	70 feet.	80 feet.	90 feet.	100 feet.	110 feet.	120 feet.		
Inches.	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Ins.*	
12	50	60	70	80	.....	.....	.....	.....	.....	8.3	.....
13	60	80	90	100	.....	.....	.....	.....	.....	8.5	23
14	70	90	110	120	140	150	.....	.....	.....	8.7	48
15	90	110	130	150	170	180	190	.....	.....	8.9	91
16	110	130	160	180	200	220	230	240	.....	9.2	117
17	130	160	180	210	230	260	280	290	310	9.4	142
18	160	180	210	240	270	300	320	350	370	9.6	136
19	180	210	250	280	310	350	380	410	430	9.9	135
20	210	250	280	320	360	400	440	470	500	10.1	104
21	240	280	320	370	410	460	500	540	580	10.4	127
22	280	310	360	410	470	520	570	620	670	10.6	135
23	.....	350	410	470	520	590	640	700	760	10.9	103
24	.....	390	450	520	590	660	720	780	850	11.1	105
25	.....	430	500	580	650	730	800	880	950	11.3	85
26	.....	470	550	630	720	800	890	980	1,070	11.6	93
27	.....	.....	610	690	790	880	980	1,080	1,190	11.9	83
28	.....	.....	660	760	860	960	1,080	1,190	1,310	12.1	63
29	.....	.....	.....	820	930	1,040	1,170	1,300	1,440	12.4	51
30	.....	.....	.....	880	1,000	1,130	1,270	1,420	1,570	12.7	42
31	.....	.....	.....	940	1,070	1,220	1,380	1,550	1,720	12.9	21
32	.....	.....	.....	1,010	1,150	1,310	1,490	1,680	1,870	13.2	28
33	.....	.....	.....	.....	1,230	1,410	1,610	1,820	2,020	13.5	22
34	.....	.....	.....	.....	1,310	1,510	1,740	1,960	2,180	13.9	22
35	.....	.....	.....	.....	1,390	1,620	1,870	2,110	2,330	14.3	17
36	.....	.....	.....	.....	1,470	1,720	1,990	2,260	2,500	14.7	13
37	.....	.....	.....	.....	.....	1,810	2,120	2,410	2,660	15.2	6
38	.....	.....	.....	.....	.....	1,900	2,250	2,550	2,820	15.8	4
39	.....	.....	.....	.....	.....	.....	2,390	2,690	2,980	16.4	5
40	.....	.....	.....	.....	.....	.....	2,530	2,840	3,150	17.0	1
											1,822

TABLE 32.—*Volume of yellow pine in board feet (Scribner decimal C rule) on basis of diameter, merchantable length in 16-foot logs.*

Diameter breast high.	Merchantable length 16-foot logs.					
	1 log.	2 logs.	3 logs.	4 logs.	5 logs.	6 logs.
Inches.	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*	*Board feet.*
13	50	80	.....	.....	.....	.....
14	60	100	140	190	.....	.....
15	70	120	160	210	.....	.....
16	80	140	180	240	.....	.....
17	100	160	210	270	.....	.....
18	120	190	240	310	380	.....
19	140	220	270	350	430	.....
20	160	250	310	400	490	.....
21	.....	290	360	450	550	.....
22	.....	330	410	500	610	.....
23	.....	380	460	560	680	.....
24	.....	420	520	630	760	.....
25	.....	470	580	700	840	.....
26	.....	530	640	780	920	1,060
27	.....	580	710	860	1,010	1,150
28	.....	630	790	950	1,100	1,250
29	.....	680	870	1,040	1,200	1,360
30	.....	730	960	1,130	1,300	1,470
31	.....	780	1,050	1,230	1,410	1,590
32	.....	830	1,140	1,340	1,530	1,710
33	.....	880	1,240	1,460	1,660	1,830
34	.....	930	1,340	1,580	1,780	1,960
35	.....	980	1,440	1,710	1,910	2,090
36	.....	.....	1,540	1,830	2,040	2,220
37	.....	.....	1,640	1,950	2,160	2,340
38	.....	.....	1,740	2,060	2,280	2,450
39	.....	.....	.....	2,160	2,400	2,560
40	.....	.....	.....	2,260	2,520	2,670